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# Do underwriters compete in IPO pricing?

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# Do Underwriters Compete in IPO pricing?*

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**Abstract**

We propose and implement a direct test of the hypothesis of oligopolistic competition in the U.S. underwriting market against the alternative of implicit collusion among underwriters. We construct a simple model of interaction between heterogenous underwriters and heterogenous firms and solve it under two alternative assumptions: oligopolistic competition among underwriters and implicit collusion among them. The two solutions lead to different equilibrium relations between the compensation of underwriters of different quality on one hand and the time-varying demand for public incorporation on the other hand. Our empirical results, obtained using 39 years of IPO data, are generally consistent with the implicit collusion hypothesis – banks, especially larger ones, seem to internalize the effects of their underwriting fees and IPO pricing on their rivals.

**Keywords:** IPOs, underwriters, competition, collusion

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# 1 Introduction

The U.S. IPO underwriting market is highly profitable. IPO gross spreads, most of which cluster at 7%, seem high in absolute terms and are high relative to other countries (e.g., Chen and Ritter (2000), Torstila (2003), Abrahamson, Jenkinson and Jones (2011), and Kang and Lowery (2014)). In addition, returns on IPO stocks on the first day of trading (i.e. IPO underpricing) tend to be even higher than underwriting spreads (e.g., Loughran, Ritter and Rydqvist (1994), Ritter and Welch (2002), Aggarwal, Prabhala and Puri (2002), and Ljungqvist and Wilhelm (2003)). The allocation of IPO shares is at the discretion of the underwriters, which are rewarded by investors, who benefit from high first-day returns. The indirect compensation of the underwriters typically takes the form of "soft" dollars, such as abnormally high trading commissions (e.g., Loughran and Ritter (2004), Reuter (2006), Nimalendran, Ritter and Zhang (2007), and Goldstein, Irvine and Puckett (2011)), spinning (e.g., Liu and Ritter (2010)), and laddering (e.g., Griffin, Harris and Topaloglu (2007) and Hao (2007)).

There is an ongoing debate as to whether the high profitability of the U.S. IPO underwriting market is suggestive of implicit collusion in price setting among underwriters – i.e. a situation in which underwriters take into account the externalities that their underwriting spreads and IPO pricing impose on other banks – or, alternatively, of oligopolistic competition among underwriters. On one side of the debate, Chen and Ritter (2000) show that IPO underwriting spreads in the U.S. cluster at 7% and argue that the U.S. IPO underwriting market is likely to be characterized by "strategic price setting" (i.e. implicit collusion). Similarly, Abrahamson, Jenkinson and Jones (2011) find no evidence that the high gross spreads in the U.S. can be justified by non-collusive reasons, such as legal expenses, retail distribution costs, litigation risk, high cost of research analysts, and the possibility that higher fees may be offset by lower underpricing.

On the other side of the debate, Hansen (2001) finds that the U.S. IPO underwriting market is characterized by low concentration and high degree of entry, that IPO spreads did not decline following the SEC announcements of allegations of collusion, and that the underwriting spreads of IPOs that do not belong to the 7% cluster are typically higher than 7%. He interprets this evidence as suggesting that investment banks may still compete for IPO underwriting business on dimensions other than pricing, for example, underwriter prestige (e.g., Beatty and Ritter (1986), Carter and Manaster (1990), and Chemmanur and Fulghieri (1994)), analyst coverage and investment recommendations (e.g., Dunbar (2000), Krigman, Shaw and Womack (2001), Cliff and Denis (2004), and Liu and Ritter (2011)), and aftermarket price support (e.g., Ellis, Michaely and O'Hara (2000) and Lewellen (2006)).

In this paper we contribute to this debate by proposing and implementing new tests of the hypotheses of oligopolistic competition versus implicit collusion in price setting in the U.S. IPO underwriting market. Our strategy consists of two steps. First, we construct a model of the IPO underwriting market and solve it under two distinct assumptions regarding the competitive structure of the market. In the first setting, characterized by oligopolistic competition, we assume that each underwriter sets the price for its services with the objective of maximizing its own expected profit, while taking into account the optimal responses of other underwriters. In the second setting, characterized by implicit collusion, we assume that underwriters cooperate in price setting, i.e. they choose underwriting fees and set IPO offer prices with the goal of maximizing their joint expected profit.

Both solutions of the model yield equilibrium relations between the proportional and absolute (dollar) compensation of higher-quality and lower-quality underwriters on one hand and firms' demand for public incorporation on the other hand. The comparative statics obtained in the oligopolistic competition setting are, in many cases, different from those obtained in the implicit collusion setting. We are agnostic ex-ante regarding the structure of the market and, therefore, our tests do not favor either of the two hypotheses. It is important to note that our term "implicit collusion" refers to internalization by banks of the effects of their IPO pricing and underwriting spreads on other underwriters, and does not preclude the possibility that underwriters compete for IPO business via other channels such as providing (star) analyst coverage and/or aftermarket price support, getting access to favorable investor clientele, etc.

Our second step is to employ U.S. IPO data during the period 1975–2013 to test predictions that follow from the two versions of the model and examine whether oligopolistic competition or implicit collusion fits the data better. Our exercise is in the spirit of Rotemberg and Woodford (1992), who solve an industry equilibrium model under the collusion scenario and, alternatively, under the competitive scenario, and examine empirically which of the two settings fits more closely the effects of U.S. military spending on the economy. While most of the literature examining potential collusion in the IPO underwriting market focuses on the direct component of underwriter compensation (IPO spreads), Kang and Lowery (2014) demonstrate that it is crucial to also account for the indirect component of banks' compensation (IPO underpricing) in an analysis of IPO market structure. Thus, in our empirical tests, we account for both IPO spreads and underpricing in estimating underwriter compensation.

Our model features investment banks of heterogenous quality that provide underwriting services to heterogeneous firms: Higher-quality underwriters provide higher value-added to firms whose IPOs they underwrite. Providing underwriting services entails costs, which depend both on the volume of underwritten IPOs and on the demand for public incorporation. Firms choose whether to go public or stay private and, in case they decide to go public, which underwriter to employ for their IPO, with the objective of maximizing the benefits of being public net of IPO costs. The resulting equilibrium outcome is similar to that in Fernando, Gatchev and Spindt (2005) – an assortative matching of firms and underwriters: Higher-quality underwriters charge higher fees; firms with relatively high valuations employ higher-quality underwriters; medium-valued firms are taken public by lower-quality underwriters; and low-valued firms stay private, since for them the costs of going public outweigh the benefits of public incorporation. Unlike Fernando, Gatchev and Spindt (2005) and Liu and Ritter (2011), who assume oligopolistic competition among underwriters, we solve our model twice: first, under the oligopolistic competition scenario, and, second, under the implicit collusion scenario.

The model's main comparative statics are as follows. First, in the oligopolistic competition scenario, the mean equilibrium proportional underwriter compensation (i.e. compensation relative to IPO proceeds) is predicted to be increasing in the demand for public incorporation for both higher-quality and lower-quality underwriters, because banks are more selective in the choice of IPO firms when the demand for going public is high. This selectivity leads to higher average value of IPO firms going public when the demand for public incorporation is higher, empowering underwriters to charge higher (direct and indirect) fees.

In the collusive setting, the relation between the mean proportional underwriter compensation and the demand for public incorporation is positive for higher-quality banks, for reasons similar to those in the competitive case. On the other hand, the relation is U-shaped for lower-quality underwriters. The reason for the decreasing part of the relation is that when the demand for public incorporation is low, it is in the banks' combined interest to set relatively high fees for lower-quality banks. This pricing strategy effectively results in channeling most IPOs to higher-quality banks. When the demand for public incorporation is high, on the other hand, both higher-quality and lower-quality banks underwrite larger IPOs, enabling them to demand higher compensation.

Second, in the oligopolistic competition scenario, the ratio of mean equilibrium dollar compensation received by higher-quality underwriters to that received by lower-quality underwriters is predicted to be decreasing in the demand for public incorporation. The reason is that in cold markets, lower-quality underwriters have to set fees that are significantly lower than those of higher-quality underwriters to get some share of the underwriting business. This relative difference declines, however, as the demand for public incorporation increases.

In the collusive scenario, the relation between the ratio of mean dollar compensation charged by higher-quality banks to that charged by lower-quality banks on one hand and the demand for public incorporation on the other hand is shown to be hump-shaped. The reason is that when the demand for going public is low, underwriters' joint profit is maximized by channelling most IPOs to the higher-quality banks. To achieve this, the colluding banks choose high fees for lower-quality banks relative to those of higher-quality ones. However, the incentive to channel IPOs to higher-quality banks weakens as the demand for public incorporation increases, because of increasing marginal costs of underwriting. This explains the increasing portion of the hump-shaped relation between the ratio of dollar compensation charged by higher-quality banks to that charged by lower-quality banks on one hand and the demand for public incorporation on the other hand. As the demand for IPO underwriting services keeps increasing, both higher-quality and lower-quality banks underwrite higher-valued IPOs, reducing the differences between the sizes of IPOs underwritten by banks of different quality and between the absolute (dollar) compensation they receive in equilibrium. In other words, the stronger the demand for public incorporation, the weaker the effect of one bank's compensation on the demand for another bank's underwriting services, and the lower the banks' incentives to collude. This explains the decreasing portion of the hump-shaped relation.

Our empirical results are generally in line with the implicit collusion model and are less supportive of the oligopolistic competition model. First, consistent with the former and inconsistent with the latter, the mean proportional compensation of lower-quality underwriters exhibits a U-shaped relation with the demand for public incorporation, both when we focus exclusively on the direct component of underwriter compensation, i.e. underwriting spread, and also when we account for its potential indirect component, i.e. kickbacks to underwriters due to underpricing. Second, the relation between the ratio of higher-quality banks' compensation for underwriting services to that of lower-quality banks' compensation on one hand and the demand for public incorporation on the other hand is hump-shaped. This relation is significant both economically and statistically, and robust to various definitions of higher-quality and lower-quality underwriters. However, our results suggest that implicit collusion, if present, is not likely to take the form of perfect price discrimination. The reason is that comparative statics following from a model of perfect price discrimination are very different from the model of implicit collusion analyzed in this paper, in which underwriters pseudo-compete on price by setting IPO fees and pricing to achieve optimal allocation of IPOs.

Consistent with an extension of the model in which we examine a conceivable situation in which only a subset of larger, more reputable underwriters consider coordinating IPO fees, the empirical relations discussed above hold when we restrict the sample to underwriters with the highest reputation. This is consistent with implicit collusion being more plausible among large banks, which are less interested in coordinating prices with their fringe rivals. Also, the empirical results are not driven by underwriter syndication (i.e. IPOs with multiple book runners), which has become especially prevalent in recent years. In particular, the results generally hold in the pre–2000 subsample, in which syndication is rare, and are robust to performing the tests on a sample of only lead book runners.

The static nature of our model, coupled with time-series empirical predictions, is a potential limitation of our setting. In a dynamic setting, underwriters' incentives to collude may be time-varying. In particular, since the benefits of deviating from implicit collusion are higher when the demand for public incorporation is high (e.g, Rotemberg and Saloner (1986) and Rotemberg and Woodford (1992)), it is possible that underwriters would implicitly collude in times of relatively low demand for going public and compete in times of relatively high demand. As the comparative statics of the collusive and competitive models differ mostly when the demand for public incorporation is relatively low, our evidence can be interpreted as consistent with a dynamic setting in which underwriters tend to engage in implicit collusion in price setting when the demand for their services is low.

To summarize, our paper's contribution is twofold. First, we propose novel tests of the hypothesis of oligopolistic competition in the U.S. IPO underwriting market against the alternative hypothesis of implicit collusion in setting IPO underwriting spreads and offer prices. Our tests are based on matching the directional predictions derived from two versions of a model of interaction between heterogenous underwriters and heterogenous firms – one in which underwriters compete in IPO pricing and the other in which they cooperate – to the relations observed in the data. Second, our empirical findings contribute to the debate regarding the structure of the U.S. IPO underwriting market. Our results are more consistent with the hypothesis of implicit collusion among underwriters in IPO price setting. This is in line with recent studies (e.g., Liu and Ritter (2011)), which suggest that by providing analyst coverage and/or aftermarket support, underwriters compete less fiercely on the IPO pricing dimension.

The paper proceeds as follows. The next section presents the model and its solution under two scenarios: oligopolistic competition and implicit collusion, and derives two sets of empirical predictions. In Section 3 we conduct empirical tests of these predictions. Section 4 concludes. Appendix A provides proofs of theoretical results. Appendices B, C, and D contain extensions of the baseline model.

# 2 Model

In this section we first set up a simple model of interaction between two heterogenous underwriters on one hand and a mass of heterogenous firms that are considering going public on the other hand. We solve the model under two distinct scenarios. The first is oligopolistic competition, in which underwriters set their compensation non-cooperatively, and each underwriter maximizes its profit without internalizing the effects of its decisions on the other underwriter's profit. The second scenario is implicit collusion, in which the two underwriters make their decisions cooperatively, with the objective of maximizing their combined profit.

## 2.1 Setup

There is a mass of firms of size $N$, which are initially private. These firms are considering going public because their values would be higher under public incorporation. The firms trade off the net benefits of public incorporation versus the costs of an IPO. In what follows, we refer to $N$ as "the demand for public incorporation". Private firms' values are assumed to be distributed uniformly between zero and one:

$$V_i \sim \mathbb{U}(0,1], \tag{1}$$

where $V_i$ is firm $i$'s pre-IPO value.

Each firm may decide to go public or to stay private, and firms make these decisions simultaneously and non-cooperatively. A firm's IPO needs to be underwritten by a bank (underwriter). We assume that there are two banks, denoted $B_1$ and $B_2$. Going public has benefits, which we assume to be described by underwriter-specific value-added parameters, $\alpha_j$ for bank $j$. We assume, without loss of generality, that $\alpha_1 > \alpha_2 > 0$ and refer to $B_1$ and $B_2$ as "higher-quality" and "lower-quality" underwriters respectively. Going public is costly: the fee charged by bank $j$ for underwriting firm $i$'s IPO is $F_{i,j}$. If a firm with pre-IPO value $V_i$ decides to go public using underwriter $j$, its post-IPO value, $V_{i,j}$, equals

$$V_{i,j} = V_i(1+\alpha_j) - F_{i,j}. \tag{2}$$

Firm $i$ decides to go public using underwriter $j$ if its post-IPO value, $V_{i,j}$, net of underwriting fee, $F_{i,j}$, exceeds both its pre-IPO value and its value following IPO underwritten by the other bank net of that bank's fee.

We assume that each bank charges a flat fee for underwriting an IPO, $F_{i,j} = \lambda_j$, which is chosen after observing the demand for public incorporation, $N$, and the distribution of firms' pre-IPO values. In what follows, we use the terms "underwriter fee" and "underwriter compensation" interchangeably.

For a given level of demand for public incorporation, $N$, banks face increasing marginal costs of providing underwriting services. In addition, the costs of underwriting a given mass of IPOs are assumed to be decreasing in the demand for public incorporation. In particular, for underwriter $j$, the total cost of underwriting $N_j$ IPOs, $TC_j(N_j, N)$, is

$$TC_j(N_j, N) = \frac{c_j}{N^k} N_j^2, \tag{3}$$

where $c_j$ is underwriter-specific and $0 \leq k < 1$.

## 2.2 Discussion of assumptions

**IPO as a method of obtaining public incorporation**

Since the focus of this paper is on the structure of the IPO underwriting market, in the model we assume that in order for a firm to become publicy-traded, it has to conduct an IPO. However, in reality, there is another viable "exit" choice – a private firm can be acquired by a publicly-traded one (e.g., Brau, Francis and Kohers (2003), Poulsen and Stegemoller (2008), Bayar and Chemmanur (2012), and Chemmanur, He, He and Nandy (2015)). In the empirical analysis we account for acquisitions of private firms by public ones as well as for IPOs in constructing a measure of the demand for public incorporation.

**Mass of firms**

We treat the total number of firms that are considering going public, $N$, and the number of firms that decide to have their IPOs underwritten by a particular bank $j$, $N_j$, as continuous variables, i.e. we consider masses of firms. In doing so, we follow a large body of industrial organization literature (e.g., Ruffin (1971), Okuguchi (1973), Dixit and Stiglitz (1977), Loury (1979), von Weizsäcker (1980), and Mankiw and Whinston (1986)). Seade (1980) justifies the practice of treating the number of firms as a continuous variable by arguing that it is always possible to use continuous differentiable variables and restrict attention to integer realizations of these variables.

**Distribution of firm values**

The assumption that firm values are distributed uniformly on the interval $(0, 1]$ is made for analytical convenience. The intuition for the model's results and comparative statics does not depend on the particular distribution of firm values.

**Two underwriters**

The assumption that there are two underwriters is made for analytical convenience. While it is possible to obtain an analytical solution to a model with any number of underwriters, the equilibrium quantities become algebra-intensive when the number of underwriters exceeds two, to the extent that makes it impossible to analyze the model's comparative statics analytically. In Appendix B, we examine the case of three underwriters (all, none, or part of which may collude in setting their fees) and show that the model's quantitative results are robust to the case of three underwriters.

**IPO value added and IPO size**

Public incorporation has numerous benefits, as well as costs. The dollar value of many of the benefits of public incorporation, such as lower cost of capital, following from improved liquidity (e.g., Amihud and Mendelson (1986)), improved operating and investment decision making (e.g., Rothschild and Stiglitz (1971), Shah and Thakor (1988), and Chod and Lyandres (2011)), and improved mergers and acquisitions policy (e.g., Zingales (1995) and Hsieh, Lyandres, and Zhdanov (2010)), is likely to be increasing in firm size. While there are other benefits of public incorporation whose value is not necessarily larger for larger firms, such as outside monitoring (e.g., Holmström and Tirole (1993)), loosening of financial constraints (e.g., Hsu, Reed, and Rocholl (2010)), certification (Lee and Wahal (2004)), and favorable analyst coverage (e.g., James and Karceski (2006)), the overall dollar benefits of public incorporation are likely to be positively related to the size of the firm going public, hence the assumption that the value added of an IPO is proportional to firm size.

**Heterogeneous underwriter quality**

Underwriters' value added can take various forms, such as reputation, certification, and/or analyst coverage provision (e.g., Liu and Ritter (2011)). Alternatively, the value added may be due to underwriters' marketing and distribution networks (e.g., Biais, Bossaerts and Rochet (2002)). We assume that underwriters are heterogeneous in their quality, i.e. in the value they add to the firms whose IPOs they underwrite. Higher-quality underwriters may have an advantage at marketing an issue through a road show, selling an issue to longer-term investors, stabilizing stock prices in the aftermarket, and providing analyst coverage of a newly issued stock. Empirically, underwriter quality is positively related to post-IPO long-run performance (e.g., Nanda and Yun (1995) and Carter, Dark and Singh (1998) and Dong, Michel and Pandes (2011))). The assumption of heterogenous underwriter quality is crucial for the model's solution, as it is based on assortative matching of firms and underwriters in equilibrium.

**Flat underwriter compensation**

The assumption that underwriter compensation is flat, i.e. dependent on the identity of the underwriter but not on the size of the firm that is going public is made for analytical convenience, since a model in which underwriter fees depend on firm size does not have analytical solutions. However, this assumption is inconsistent with empirical evidence that suggests that underwriter compensation has both fixed and variable components (e.g., Altinkiliç and Hansen (2000)). To examine whether this assumption drives the model's results, in Appendix C we solve numerically a generalized version of the model, in which we assume that underwriter compensation has two components: a fixed fee, $\lambda_j$, which is identical for all firms underwritten by bank $j$, and a variable component, $\mu_j V_i$, which increases in the size of the firm going public. We show that the results of the generalized model with variable IPO fees are consistent with the baseline model with flat IPO fees, solved analytically.

**IPO spreads and kickbacks considered together**

Underwriter compensation consists of two components. The first, direct, component is the fee paid by the issuing firm to its IPO underwriter (i.e. IPO spread). The second, indirect, component is the money left on the table at the time of the IPO (i.e. IPO underpricing), part of which is argued to accrue to underwriters (e.g., Reuter (2006), Nimalendran, Ritter and Zhang (2007), and Goldstein, Irvine and Puckett (2011)). In the model, we refer to all the (direct and indirect) compensation a bank receives in exchange for providing underwriting services as underwriter fee (or IPO fee). In reality, these two components of underwriter compensation are decided at different times: underwriting spread is determined during the process of a search for an underwriter ("beauty contest"), while underpricing is determined after the underwriter has been chosen. We assume that the two components of underwriter compensation are set simultaneously in order to construct the most parsimonious model of interaction between heterogenous firms and heterogenous underwriters. Simultaneous determination of the two components of underwriter compensation assumes away information asymmetries between firms, underwriters, and investors during the IPO process. In the absence of information asymmetries, all players can compute the total transfers between firms and underwriters, regardless of the form these transfers take. This simplification allows us to focus on the overall compensation received by underwriters.

**Marginal costs of underwriting**

Our specification of the costs of underwriting IPOs captures two effects. First, conditional on the demand for public incorporation, the total costs of underwriting for a given bank are likely convex in the mass of underwritten IPOs, i.e. the marginal costs of underwriting are increasing in the mass of IPOs that bank $j$ underwrites ($N_j$) for a given demand for public incorporation ($N$). This assumption is consistent with Khanna, Noe and Sonti's (2008) model of inelastic supply of labor in investment banking, with empirical estimates of underwriters' cost function (e.g., Altinkiliç and Hansen (2000)), and with empirical evidence in Lowry and Schwert (2002), who find that when the demand for public incorporation is high, investment banks struggle to provide service to all firms interested in going public. The assumption of increasing marginal costs of underwriting is crucial as it ensures that both banks underwrite a positive mass of IPOs in equilibrium.

Second, the marginal costs of underwriting a given mass of IPOs are decreasing in the demand for public incorporation, $N$, as marketing and/or distribution costs are likely to be lower when the demand for public incorporation is high. However, this assumption is not crucial to any of the results, which continue to hold in the limiting case of the costs of underwriting being independent of the demand for public incorporation ($k = 0$).

The assumption that the negative relation between the total cost of underwriting and the demand for public incorporation is weaker than multiplicative inverse ($k < 1$) is made for analytical convenience. This assumption results in a positive relation between the marginal cost of underwriting the last IPO in a given range of values of firms going public and the demand for public incorporation, $N$. Without this assumption (i.e. if $k$ would equal or exceed one), a corner solution would be reached for sufficiently large $N$, in which all firms considering going public would conduct an IPO and have it underwritten by one bank. The assumption $k < 1$ precludes the possibility of this corner solution, which simplifies the model considerably.

Third, we assume that underwriters are potentially heterogenous in their cost functions. This assumption does not drive any of the results, which hold in the limiting case of identical cost functions of the two underwriters.

## 2.3 Underwriters' objective functions

Assume first that the underwriting market is competitive in the sense that the two banks set their underwriting fees simultaneously and non-cooperatively. Each bank's objective is to maximize its own profit, $\pi_j$ for bank $j$, while taking into account the optimal response of the other underwriter.

We can write bank $j$'s optimization problem as

$$\pi_j = \max_{\lambda_j} \left( \lambda_j N_j^* \left( \lambda_j, \lambda_{-j}, N \right) - \frac{c_j}{N^k} \left( N_j^* \left( \lambda_j, \lambda_{-j}, N \right) \right)^2 \right) =$$
$$\max_{\lambda_j} \left( \lambda_j N \int_{i=0}^{1} \mathbb{I}_{i,j}^* d_i - \frac{c_j}{N^k} \left( N \int_{i=0}^{1} \mathbb{I}_{i,j}^* d_i \right)^2 \right), \tag{4}$$

where $N_j^*(\lambda_j, \lambda_{-j}, N)$ is the equilibrium mass of IPOs underwritten by bank $j$ as a function of its own fee, $\lambda_j$, the other bank's fee, $\lambda_{-j}$, and the demand for public incorporation, $N$; and $\mathbb{I}_{i,j}^*$ is an indicator that equals one if bank $j$ underwrites the IPO of a firm with pre-IPO value $V_i$ in equilibrium and equals zero otherwise.

Assume now that the underwriting market is collusive in the sense that the two banks coordinate their fees, i.e. they set their fees with the objective of maximizing their combined profit, $\pi_{joint} = \pi_1 + \pi_2$. The banks' joint optimization problem becomes

$$\pi_{joint} = \max_{\lambda_1, \lambda_2} \left( \sum_{j=1}^{2} \left( \lambda_j N_j^* \left( \lambda_j, \lambda_{-j}, N \right) - \frac{c_j}{N^k} \left( N_j^* \left( \lambda_j, \lambda_{-j}, N \right) \right)^2 \right) \right) =$$
$$\max_{\lambda_1, \lambda_2} \left( \sum_{j=1}^{2} \left( \lambda_j N \int_{i=0}^{1} \mathbb{I}_{i,j}^* d_i - \frac{c_j}{N^k} \left( N \int_{i=0}^{1} \mathbb{I}_{i,j}^* d_i \right)^2 \right) \right). \tag{5}$$

## 2.4 Firms' strategies

After observing the fees charged by the two underwriters, each firm can pursue one of three mutually exclusive strategies: it can remain private or it can perform an IPO underwritten by one of the two banks. Firm $i$'s maximized value, $V_i^*$, is thus

$$V_i^* = \sup\{V_i, V_i(1 + \alpha_1) - \lambda_1, V_i(1 + \alpha_2) - \lambda_2\}. \tag{6}$$

It follows from (6) that each firm's optimal strategy can be summarized as follows:

**Lemma 1** *Firm $i$'s optimal strategy as a function of the two underwriters' value-added parameters, $\alpha_1$ and $\alpha_2$, and of their underwriting fees, $\lambda_1$ and $\lambda_2$, is as follows:*
*1) If $\frac{\lambda_1}{\alpha_1} > \frac{\lambda_2}{\alpha_2}$ then*

$$\textit{perform an IPO underwritten by } B_1 \textit{ if } V_i > \frac{\lambda_1 - \lambda_2}{\alpha_1 - \alpha_2},$$
$$\textit{perform an IPO underwritten by } B_2 \textit{ if } \frac{\lambda_2}{\alpha_2} < V_i \leq \frac{\lambda_1 - \lambda_2}{\alpha_1 - \alpha_2},$$
$$\textit{remain private if } V_i \leq \frac{\lambda_2}{\alpha_2}.$$

*2) If* $\frac{\lambda_1}{\alpha_1} \leq \frac{\lambda_2}{\alpha_2}$ *then*

$$\textit{perform an IPO underwritten by } B_1 \textit{ if } V_i > \frac{\lambda_1}{\alpha_1},$$
$$\textit{remain private if } V_i \leq \frac{\lambda_1}{\alpha_1}.$$

As a result, depending on the fees set by the two banks, the following situations are possible.
1) No IPOs. This happens if $\frac{\lambda_1}{\alpha_1} \geq 1$ and $\frac{\lambda_2}{\alpha_2} \geq 1$.
2) No IPOs underwritten by $B_1$. $B_2$ underwrites IPOs of firms with $V_i > \frac{\lambda_2}{\alpha_2}$. This happens if $\frac{\lambda_2}{\alpha_2} < 1 \leq \frac{\lambda_1}{\alpha_1}$.
3) No IPOs underwritten by $B_2$. $B_1$ underwrites IPOs of firms with $V_i > \frac{\lambda_1}{\alpha_1}$. This happens if $\frac{\lambda_1}{\alpha_1} \leq \frac{\lambda_2}{\alpha_2}$ and $\frac{\lambda_1}{\alpha_1} < 1$.
4) $B_2$ underwrites IPOs of firms with $V_i \in (\frac{\lambda_2}{\alpha_2}, \frac{\lambda_1-\lambda_2}{\alpha_1-\alpha_2}]$. $B_1$ underwrites IPOs of firms with $V_i > \frac{\lambda_1-\lambda_2}{\alpha_1-\alpha_2}$. This happens if $\frac{\lambda_2}{\alpha_2} < \frac{\lambda_1}{\alpha_1}$ and $\frac{\lambda_1-\lambda_2}{\alpha_1-\alpha_2} < 1$.

The first case above is trivial. If the fees charged by both banks are too high to induce even the highest-valued firm (which would benefit the most from an IPO) to go public, then no firm would choose to do an IPO. In the second scenario, the higher-quality bank's ($B_1$) fee is too high; therefore even the most valuable firm, which could benefit the most from its IPO being underwritten by $B_1$, prefers to have its IPO underwritten by the lower-quality bank ($B_2$) despite the lower value increase brought by $B_2$. In the third case, the benefit of an IPO with $B_1$ net of its underwriting fee exceeds the net benefit of an IPO with $B_2$ even for the least valuable firm that would still benefit from an IPO with $B_2$. Therefore, all IPOs are underwritten by $B_1$. Finally, in the fourth case, both banks underwrite IPOs: $B_1$ underwrites IPOs of companies whose valuations are sufficiently high, so that the higher benefit of an IPO underwritten by $B_1$ outweighs its higher fee, while IPOs of firms with lower valuations (that are still sufficiently high to go through an IPO with $B_2$) are underwritten by $B_2$.

The next result establishes that in both the oligopolistic competition scenario and the implicit collusion scenario, in equilibrium, only the fourth case, in which both banks underwrite some IPOs, is possible.

**Lemma 2** *In both the oligopolistic competition and implicit collusion scenarios, equilibrium underwriters' fees satisfy* $\frac{\lambda_2^*}{\alpha_2} < \frac{\lambda_1^*}{\alpha_1}$ *and* $\frac{\lambda_1^*-\lambda_2^*}{\alpha_1-\alpha_2} < 1$. *Firms with values* $V_i \leq \frac{\lambda_2^*}{\alpha_2}$ *remain private. Firms with values* $\frac{\lambda_2^*}{\alpha_2} < V_i \leq \frac{\lambda_1^*-\lambda_2^*}{\alpha_1-\alpha_2}$ *go public and have their IPOs underwritten by* $B_2$. *Firms with values* $V_i > \frac{\lambda_1^*-\lambda_2^*}{\alpha_1-\alpha_2}$ *go public and have their IPOs underwritten by* $B_1$.

The marginal cost of underwriting the first IPO (i.e. the first “infinitesimal unit of IPO”, as we treat the number of firms going public as a continuous variable) approaches zero. In the oligopolistic competition case, in which each bank sets its underwriting fee without accounting for the externality that its fee imposes on the other underwriter, each bank always prefers underwriting the first IPO at any fee greater than zero to underwriting no IPOs, which results in both banks underwriting positive masses of IPOs in equilibrium.

In the collusive case, in which the banks set their fees jointly, it is also always advantageous to have each bank underwrite a strictly positive mass of IPOs. The reason is as follows. Even if the two banks’ combined revenue is maximized when all IPOs are underwritten by the higher-quality bank, moving the last infinitesimal unit of underwritten IPO to the lower-quality bank has a negligible (negative) effect on the combined revenue, since the higher-quality bank can charge slightly higher fees for all other IPOs it underwrites. On the other hand, having the last unit of IPO underwritten by the lower-quality bank reduces the banks’ combined underwriting costs, as the marginal cost of underwriting the first IPO by the lower-quality bank approaches zero, while the marginal cost of underwriting the last unit of IPO by the higher-quality bank is strictly positive. Thus, having the last unit of IPO underwritten by the lower-quality bank reduces the two banks’ combined revenues by a lower amount than the reduction in the two banks combined underwriting costs. As a result, both banks underwrite some IPOs in the collusive equilibrium.

To summarize, in equilibrium, underwriting fees are set in such a way that each bank gets a positive share of the IPO underwriting market, in both competitive and collusive equilibria. Highest-valued firms’ IPOs are underwritten by the higher-quality bank, lower-valued firms’ IPOs are underwritten by the lower-quality bank, whereas lowest-valued firms stay private. This outcome is consistent with anecdotal evidence that suggests that more reputable banks tend to underwrite larger IPOs, with Fernando, Gatchev and Spindt’s (2005) assortative matching model of firms and underwriters, in which firm quality and underwriter quality are positively correlated, and with recent evidence of assortative matching in the IPO market (e.g., Akkus, Cookson and Hortacsu (2015)) and in the private investment in public equity (PIPE) market (e.g., Dai, Jo and Schatzberg (2010)). More generally, this matching is consistent with the efficient rationing rule (e.g., Tirole (1988)).

## 2.5 Equilibrium underwriter fees and profits

### 2.5.1 Oligopolistic competition

Using the result in Lemma 2, we can rewrite bank $j$'s optimization problem in (4) as

$$\pi_j = \max_{\lambda_j} \left( \lambda_j \left( N \left( \overline{V_j} - \underline{V_j} \right) \right) - \frac{c_j}{N^k} \left( N \left( \overline{V_j} - \underline{V_j} \right) \right)^2 \right), \tag{7}$$

$$\underline{V_1} = \frac{\lambda_1 - \lambda_2}{\alpha_1 - \alpha_2} \text{ and } \overline{V_1} = 1, \tag{8}$$

$$\underline{V_2} = \frac{\lambda_2}{\alpha_2} \text{ and } \overline{V_2} = \frac{\lambda_1 - \lambda_2}{\alpha_1 - \alpha_2}, \tag{9}$$

where the mass of IPOs underwritten by bank $j$, $N_j = N\left(\overline{V_j} - \underline{V_j}\right)$, is determined by the two "indifference thresholds ": $\underline{V_1} = \overline{V_2}$ determines the value of the marginal firm that is indifferent between having its IPO underwritten by $B_1$ or $B_2$, and $\underline{V_2}$ determines the value of the marginal firm that is indifferent between having its IPO underwritten by $B_2$ and staying private. Solving the system of two first-order conditions that follow from (7) results in equilibrium fee level of each bank under the oligopolistic competition scenario, $\lambda^*_{jComp}$ for bank $j$:[1,2]

$$\lambda^*_{1_{Comp}} = \frac{2\alpha_1 \left(2Nc_1 + N^k (\alpha_1 - \alpha_2)\right) \left(Nc_2\alpha_1 + N^k (\alpha_1 - \alpha_2)\alpha_2\right)}{\Phi_{Comp}}, \tag{10}$$

$$\lambda^*_{2_{Comp}} = \frac{\alpha_2 \left(2Nc_1 + N^k (\alpha_1 - \alpha_2)\right) \left(2Nc_2\alpha_1 + N^k (\alpha_1 - \alpha_2)\alpha_2\right)}{\Phi_{Comp}}, \tag{11}$$

where

$$\Phi_{Comp} = 2Nc_1 \left(2Nc_2\alpha_1 + N^k (2\alpha_1 - \alpha_2)\alpha_2\right) + N^k \left(2Nc_2\alpha_1 (2\alpha_1 - \alpha_2) + N^k \alpha_2 \left(4\alpha_1^2 - 5\alpha_1\alpha_2 + \alpha_2^2\right)\right).$$

The equilibrium mass of IPOs underwritten by each of the two banks, $N^*_{1_{Comp}}$ and $N^*_{2_{Comp}}$, are

$$N^*_{1_{Comp}} = \frac{N^{1+k}\alpha_1 \left(Nc_2\alpha_1 + N^k (\alpha_1 - \alpha_2)\alpha_2\right)}{\Phi_{Comp}}, \tag{12}$$

$$N^*_{2_{Comp}} = \frac{N^{1+k}\alpha_1\alpha_2 \left(Nc_1 + N^k (\alpha_1 - \alpha_2)\right)}{\Phi_{Comp}}. \tag{13}$$

Finally, the equilibrium profits of the two underwriters, $\pi^*_{1_{Comp}}$ and $\pi^*_{2_{Comp}}$, are

$$\pi^*_{1_{Comp}} = \frac{4N^{1+k}\alpha_1^2 \left(Nc_1 + N^k (\alpha_1 - \alpha_2)\right) \left(Nc_2\alpha_1 + N^k (\alpha_1 - \alpha_2)\alpha_2\right)^2}{\Phi^2_{Comp}}, \tag{14}$$

$$\pi^*_{2_{Comp}} = \frac{N^{1+k}\alpha_1\alpha_2^2 \left(2Nc_1 + N^k (\alpha_1 - \alpha_2)\right)^2 \left(Nc_2\alpha_1 + N^k (\alpha_1 - \alpha_2)\alpha_2\right)}{\Phi^2_{Comp}}. \tag{15}$$

[1] We verify that in both the oligopolistic competition scenario and in the implicit collusion scenario, the second derivatives of underwriters' profits with respect to their compensation are negative.

[2] We verify that in both the oligopolistic competition scenario and the implicit collusion scenario, the equilibrium conditions $\frac{\lambda_2^*}{\alpha_2} < \frac{\lambda_1^*}{\alpha_1}$ and $\frac{\lambda_1^* - \lambda_2^*}{\alpha_1 - \alpha_2} < 1$ are satisfied.

### 2.5.2 Implicit collusion

Using the result in Lemma 2, we can rewrite the two banks' joint optimization problem in (5) as

$$\pi_{joint} = \max_{\lambda_1,\lambda_2} \left( \sum_{j=1}^{2} \left( \lambda_j \left( N \left( \overline{V_j} - \underline{V_j} \right) \right) - \frac{c_j}{N^k} \left( N \left( \overline{V_j} - \underline{V_j} \right) \right)^2 \right) \right), \tag{16}$$

where $\overline{V_j}$ and $\underline{V_j}$ for the two banks are given in (8) and (9), respectively. Solving the system of two first-order conditions that follow from (16) results in equilibrium fees under the implicit collusion scenario, $\lambda^*_{jColl}$ for bank $j$:

$$\lambda^*_{1Coll} = \frac{N^k \alpha_1 \left( N c_2 \alpha_1 + N^k (\alpha_1 - \alpha_2) \alpha_2 \right) + N c_1 \left( 2 N c_2 \alpha_1 + N^k (2\alpha_1 - \alpha_2) \alpha_2 \right)}{\Phi_{Coll}}, \tag{17}$$

$$\lambda^*_{2Coll} = \frac{\alpha_2 \left( N c_1 \left( 2 N c_2 + N^k \alpha_2 \right) + N^k \left( N c_2 \alpha_1 + N^k (\alpha_1 - \alpha_2) \alpha_2 \right) \right)}{\Phi_{Coll}}, \tag{18}$$

where

$$\Phi_{Coll} = 2 \left( N c_1 \left( N c_2 + N^k \alpha_2 \right) + N^k \left( N c_2 \alpha_1 + N^k (\alpha_1 - \alpha_2) \alpha_2 \right) \right).$$

The equilibrium mass of IPOs underwritten by each of the two banks, $N^*_{1Coll}$ and $N^*_{2Coll}$, are

$$N^*_{1Coll} = \frac{N^{2+k} c_1 \alpha_2^2}{2\Phi_{Coll}}, \tag{19}$$

$$N^*_{2Coll} = \frac{N^{1+k} \left( N c_2 \alpha_1 + N^k (\alpha_1 - \alpha_2) \alpha_2 \right)}{\Phi_{Coll}}, \tag{20}$$

and the equilibrium combined profit of the two banks, $\pi^*_{joint_{Coll}}$,

$$\pi^*_{joint_{Coll}} = \frac{N^{1+k} \left( N \left( c_1 \alpha_2^2 + c_2 \alpha_1^2 \right) + N^k (\alpha_1 - \alpha_2) \alpha_1 \alpha_2 \right)}{2\Phi_{Coll}}. \tag{21}$$

After having derived the underwriters' equilibrium profits in the oligopolistic competition and implicit collusion scenarios, we compare them in order to verify that the underwriters do not have incentives to deviate from the collusive outcome in our static framework.[3]

**Lemma 3** *The equilibrium combined underwriter profit in the implicit collusion scenario, $\pi^*_{joint_{Coll}}$, is larger than the sum of the underwriters' profits in the oligopolistic competition scenario, $\pi^*_{1Comp} + \pi^*_{2Comp}$.*

[3] We implicitly allow the possibility of transfers among underwriters in the case of implicit collusion between them. Without such transfers, it would be optimal for the lower-quality underwriter to deviate from the collusive outcome when the demand for public incorporation is sufficiently low.

## 2.6 Underwriter compensation, IPO size, and underwriter quality

Before proceeding to analyze the relation between the demand for public incorporation and the equilibrium underwriting fees of the two banks, we examine cross-sectional determinants of underwriting fees. In other words, we compare equilibrium IPO fees paid by firms of different sizes and firms whose IPOs are underwritten by underwriters of different quality. The results of these comparisons are summarized in the following two lemmas.

**Lemma 4** *In both the competitive and collusive scenarios, the equilibrium proportional underwriting fee for all IPOs underwritten by bank $j$, $\frac{\lambda_j^*}{V_i}$, is decreasing in IPO size, $V_i$.*

This result follows immediately from the assumption that a given bank's IPO fee is constant for all firms whose IPOs it underwrites. Lemma 4 is consistent with existing empirical evidence that proportional underwriting fee tends to be decreasing in IPO size (e.g., Ritter (1987), Beatty and Welch (1996), and Torstila (2003)), which we confirm in unreported tests using our data.

To examine the relation between the quality of an underwriter and its equilibrium compensation, we define the weighted average proportional fee of bank $j$ as the ratio of the combined fees collected by bank $j$ from all firms whose IPOs it underwrites to combined pre-IPO value of these firms:

**Definition 1** *The weighted average proportional underwriting fee of bank $j$, $\overline{RF_j}$, is*

$$\overline{RF_j} = \frac{\lambda_j^* \left( \overline{V_j} - \underline{V_j} \right)}{\int\limits_{V=\underline{V_j}}^{\overline{V_j}} V dV}. \tag{22}$$

The next result establishes the relation between the underwriters' weighted average proportional fee and their quality.

**Lemma 5** *In both the competitive and collusive scenarios, the equilibrium weighted average proportional underwriting fees of $B_1$, $\overline{RF^*_{1_{Comp}}}$ and $\overline{RF^*_{1_{Coll}}}$, are higher than the respective weighted average proportional underwriting fees of $B_2$, $\overline{RF^*_{2_{Comp}}}$ and $\overline{RF^*_{2_{Coll}}}$.*

For a threshold firm, which is indifferent between its IPO being underwritten by $B_1$ or $B_2$, the proportional fee is higher if its IPO is underwritten by $B_1$ because of the higher value-added provided by $B_1$. The proportional fee of other (more valuable) firms underwritten by $B_1$ is lower than that of the threshold firm. In addition, the proportional fee of other (less valuable) firms underwritten by $B_2$ is higher than the proportional fee of the largest firm whose IPO is underwritten by $B_2$. Lemma 5 shows that the difference between equilibrium underwriting fees of the two banks is sufficiently large that the average proportional fee paid by firms whose values exceed $\underline{V_1} = \frac{\lambda_1^* - \lambda_2^*}{\alpha_1 - \alpha_2}$ and whose IPOs are underwritten by $B_1$ exceeds the mean proportional fee paid by firms whose values are between $\underline{V_2} = \frac{\lambda_2^*}{\alpha_2}$ and $\overline{V_2} = \frac{\lambda_1^* - \lambda_2^*}{\alpha_1 - \alpha_2}$ and whose IPOs are underwritten by $B_2$. This result is consistent with the existing evidence that both underwriter spreads and IPO underpricing tend to be increasing in underwriter quality (e.g., Beatty and Welch (1996) and Cliff and Denis (2004)), and with unreported tests using our data.

Overall, the fact that the results in Lemmas 4 and 5 are consistent with the empirical evidence can be thought as partially validating the model's setting and assumptions.

## 2.7 Underwriter compensation and the demand for public incorporation

### 2.7.1 Mass of underwritten IPOs

The first intuitive result is that in both the oligopolistic competition and collusive scenarios the mass of IPOs underwritten by each bank, as well as the total mass of underwritten IPOs, is increasing in the mass of firms considering going public, $N$.

**Lemma 6** *The mass of IPOs underwritten by each bank in the competitive scenario, $N^*_{1_{Comp}}$ and $N^*_{2_{Comp}}$, and in the collusive scenario, $N^*_{1_{Coll}}$ and $N^*_{2_{Coll}}$, for $B_1$ and $B_2$ respectively, are increasing in $N$.*

The monotonic relation between the mass of IPOs underwritten by each bank in equilibrium and $N$ in both the competitive and collusive scenarios is useful, because it enables us to translate various comparative statics of the model with respect to the demand for public incorporation, $N$, into empirical predictions regarding the relations between observable quantities in the IPO market and the total number of firms going public in a particular time period. We realize, however, that the monotonic theoretical relations between the demand for public incorporation, $N$, on one hand and the total equilibrium mass of IPOs, $N^*_{1_{Comp}} + N^*_{2_{Comp}}$ and $N^*_{1_{Coll}} + N^*_{2_{Coll}}$, in the competitive and collusive scenarios respectively on the other hand, hold within a model that abstracts from the possibility of obtaining public incorporation through means other than an IPO, such as through an acquisition by a publicly-traded firm. Thus, we account for both IPOs and acquisitions of private firms by public ones when we construct an empirical proxy for the demand for public incorporation.

We now turn to examining the comparative statics of the equilibrium underwriting fees in the two scenarios with respect to the demand for public incorporation, with the objective of designing empirical tests of the implicit underwriter collusion hypothesis against the alternative of oligopolistic competition.

### 2.7.2 Proportional underwriting fees

The relation between the two banks' proportional fees on one hand and the demand for public incorporation on the other hand is summarized in the following two propositions. Proposition 1 corresponds to the oligopolistic competition scenario, while Proposition 2 considers the implicit collusion scenario.

**Proposition 1** *In a competitive underwriting market, the weighted average proportional fee of the higher-quality bank ($B_1$) and that of the lower-quality bank ($B_2$), $\overline{RF^*_{1_{Comp}}}$ and $\overline{RF^*_{2_{Comp}}}$ respectively, are increasing in $N$.*

This result is consistent with the empirical evidence in Ljungqvist and Wilhelm (2003) and Loughran and Ritter (2004) among many others, who find that the indirect component of underwriter compensation, i.e. IPO underpricing, tends to be higher when the demand for public incorporation is high. The intuition behind the positive relation between the average proportional fees of the two banks and the demand for public incorporation in the competitive case is as follows. While the mass of IPOs underwritten by each bank is increasing in the mass of firms considering an IPO, $N$, as shown in Lemma 6, the proportion of firms that go public and have their IPOs underwritten by a given bank out of the total mass of firms that are considering going public is decreasing in $N$. The reason is that the marginal cost of underwriting the last IPO in a given range of IPO values is increasing in $N$, as follows from the condition $k < 1$ in the underwriting cost function in (3). The marginal revenue of the last (least valuable) IPO in a given range of IPO values is independent of $N$. Thus, when $N$ increases, leading to an increase in the marginal cost of underwriting the last IPO in a given range of IPO values, marginal revenue has to increase in equilibrium. Higher equilibrium marginal revenue implies higher value of the last underwritten IPO in equilibrium and more narrow range of values of IPOs underwritten by each of the two banks. This outcome is consistent with the prediction of signaling models of IPOs that underwriters are more selective in choosing IPOs in hot IPO markets (e.g., Allen and Faulhaber (1989)).

The proportional fee paid by the lowest-valued firm that the lower-quality bank ($B_2$) underwrites equals $\alpha_2$, since for that firm the bank extracts the whole surplus obtained at the time of the IPO. As follows from Lemma 4, the proportional fee paid by a firm to a given bank is decreasing in the IPO value; thus, the average proportional fee paid to $B_2$ is lower than $\alpha_2$. However, since the range of values of firms whose IPOs are underwritten by $B_2$ is decreasing in $N$, the average proportional fee approaches the highest proportional fee ($\alpha_2$) as $N$ increases. While the higher-quality bank ($B_1$) does not extract the full surplus from the lowest-valued firm among those it underwrites (because that firm has the option of its IPO being underwritten instead by $B_2$), similar logic holds for $B_1$: The higher the demand for public incorporation, the narrower the range of values of firms underwritten by $B_1$. This implies that $B_1$'s average proportional fee approaches the highest proportional fee charged by $B_1$ as $N$ increases.

**Proposition 2** *In a collusive underwriting market:*
*a) the weighted average proportional fee of the higher-quality bank ($B_1$), $\overline{RF^*_{1_{Coll}}}$, is increasing in $N$;*
*b) the weighted average proportional fee of the lower-quality bank ($B_2$), $\overline{RF^*_{2_{Coll}}}$, exhibits a U-shaped relation with $N$: It is decreasing in $N$ for sufficiently low $N$ and it is increasing in $N$ for sufficiently high $N$.*

The intuition behind the positive relation between the average proportional fee of the higher-quality bank and $N$ in the collusive scenario is similar to that in the competitive scenario: Higher $N$ leads to a narrower range of values of firms underwritten by the higher-quality bank, raising its average proportional fee. The U-shaped relation between the average proportional fee of the lower-quality bank and the demand for public incorporation in the collusive case is a little subtler, as it is driven by a combination of two effects. First, as with the higher-quality bank, higher $N$ leads to a narrower range of values of firms underwritten by the lower-quality bank, raising its average proportional fee. Second, for low levels of $N$, the two banks' joint expected profit is maximized when most IPOs are underwritten by $B_1$. This is because if the banks' objective is to maximize their combined profit, then for low levels of $N$ – for which the marginal costs of underwriting are close to zero – it is optimal to channel most IPOs to the higher-quality bank, which can charge a higher underwriting fee. Allocating IPOs to the lower-quality bank would reduce the mass of IPOs underwritten by the higher-quality bank and the two banks' combined profit. To channel most of the IPOs to the higher-quality bank, the lower-quality bank's fee is set high.

The second (negative) effect of the demand for public incorporation on the lower-quality bank's fee leads to a decreasing relation between the lower-quality bank's fee and the demand for public incorporation when the latter is relatively low. As $N$ continues to increase, the higher-quality bank becomes constrained by its increasing marginal cost of underwriting, making it optimal to allocate more IPOs to the lower-quality bank. Thus, when $N$ is high, the incentives to set high fees for the lower-quality bank are weaker, making the first (positive) effect of the demand for public incorporation on the lower-quality bank's fee dominant. The combination of these two effects leads to the U-shaped relation between the demand for public incorporation and the average proportional fee charged by the lower-quality underwriter.

### 2.7.3 Absolute (dollar) underwriting fees

Next, we examine the relation between equilibrium absolute (dollar) fees charged by each of the two banks and the demand for public incorporation.

**Proposition 3** *In a competitive underwriting market, the ratio of the absolute (dollar) fee charged by the higher-quality bank ($B_1$), $\lambda^*_{1_{Comp}}$, to the fee charged by the lower-quality bank ($B_2$), $\lambda^*_{2_{Comp}}$, is decreasing in $N$.*

The intuition is as follows. When $N$ is low, the marginal costs of both underwriters are close to zero, and the only way for the lower-quality bank to underwrite some IPOs is to charge a fee that is substantially lower than that of the higher-quality bank. This leads to a high ratio of the fee of the higher-quality underwriter to that of the lower-quality underwriter. As $N$ increases, the range of values of IPOs underwritten by $B_1$ narrows, increasing the residual demand for $B_2$'s underwriting services. This encourages $B_2$ to charge higher underwriting fee, leading to a lower ratio of $B_1$'s fee to $B_2$'s fee. As a result, the relation between the demand for public incorporation and the ratio of the fee charged by the higher-quality bank to that of the lower-quality bank is negative in the oligopolistic competition scenario.

**Proposition 4** *In a collusive underwriting market, the ratio of the absolute (dollar) fee charged by the higher-quality bank ($B_1$), $\lambda^*_{1_{Coll}}$, to the fee charged by the lower-quality bank ($B_2$), $\lambda^*_{2_{Coll}}$, has a hump-shaped relation with $N$: It is increasing in $N$ for sufficiently low $N$ and is decreasing in $N$ for sufficiently high $N$.*

When the two banks maximize their combined expected profit, they internalize the effect that each bank's fee has on the demand for the other bank's underwriting services. When $N$ is low, the marginal costs of underwriting are also low, and the banks are better off channeling most IPOs to the higher-quality bank, which can charge a higher fee. Thus, when $N$ is low, the fee of the lower-quality bank is set relatively high in order to channel most IPOs to the higher-quality bank. As $N$ increases, the marginal costs of the two banks increase as well, making channelling most IPOs to the higher-quality bank less attractive. Thus, the low-quality bank's fee is chosen in a way that channels more and more IPOs to it as $N$ increases. This is achieved by lowering the fee of $B_2$ relative to that of $B_1$. As $N$ increases further, the range of values of IPOs underwritten by both banks narrows and the effects of each bank's fee on the other bank's expected profit decrease. In the extreme, when $N$ is very high, each bank's fee is determined in isolation. This leads to the negative relation between the demand for public incorporation and the ratio of the two banks' fees – similar to the competitive scenario – for relatively high $N$, and overall to a hump-shaped relation between $N$ and the ratio of the two underwriters' absolute fees in the implicit collusion scenario.

### 2.8 Empirical predictions

Our model shows that the relations between underwriters' equilibrium compensation and the demand for public incorporation depend crucially on whether the underwriters implicitly collude or compete in setting underwriting fees. The comparative statics in the competitive and collusive scenarios lead to the following empirical predictions. Propositions 1 and 2 result in empirical predictions regarding the effects of the demand for public incorporation on the average proportional compensation received by underwriters.

**Prediction 1a (Oligopolistic competition)** *Weighted average proportional underwriter compensation is expected to be increasing in the demand for public incorporation.*

**Prediction 1b (Implicit collusion)** *Weighted average proportional compensation of relatively low-quality underwriters is expected to exhibit a U-shaped relation with the demand for public incorporation. Weighted average proportional compensation of relatively high-quality underwriters is expected to be increasing in the demand for public incorporation.*

Propositions 3 and 4 lead to empirical predictions regarding the effects of the demand for public incorporation on the ratio of absolute (dollar) compensation received by higher-quality underwriters to dollar compensation received by lower-quality underwriters.

**Prediction 2a (Oligopolistic competition)** *The ratio of average absolute (dollar) compensation of relatively high-quality underwriters to average absolute compensation of relatively low-quality underwriters is expected to be decreasing in the demand for public incorporation.*

**Prediction 2b (Implicit collusion)** *The ratio of average absolute (dollar) compensation of relatively high-quality underwriters to average compensation of relatively low-quality underwriters is expected to have a hump-shaped relation with the demand for public incorporation.*

### 2.9 Extensions of the baseline model

Some of the assumptions of our simple model are restrictive. First, in reality there are multiple underwriters. Therefore, in Appendix B, we show that increasing the number of underwriters does not affect the model's qualitative conclusions. While it is possible to solve the model analytically for any number of underwriters, comparative statics become prohibitively algebra-intensive. Thus, we examine the robustness of the results in the baseline model by solving the model for the case of three underwriters.

In addition to the cases in which all underwriters collude or all of them compete, as in the baseline model, we examine the case of "partial collusion," in which two highest-quality underwriters collude in price setting, while competing with the third underwriter. It is possible that in reality larger (higher-quality) underwriters collude among themselves but compete with smaller (lower-quality) underwriters.[4] In Appendix B, we verify that even if only the two highest-quality banks collude, the comparative statics of underwriting fees and market shares within the subset of the two highest-quality banks are similar to 1) those obtained in a model in which only two banks collude, and 2) those obtained in a model in which there are three underwriters, all of which collude.

Second, in reality, underwriting fees charged by a given bank are not constant across firms and depend, among other factors, on IPO size. In the baseline model we assume, for analytical tractability, that the underwriters' only choice variable is their fixed underwriting fees. However, this assumption implies that the total fee paid by each firm to a given underwriter is independent of the size of its IPO. This implication is inconsistent with the empirical evidence that total fees paid in larger IPOs tend to be higher than those paid in smaller IPOs (e.g., Chen and Ritter (2000), Hansen (2001), and Torstila (2003)). Thus, in Appendix C we solve numerically a model in which we allow the underwriters to choose not only fixed fees but also variable fees that are increasing in IPO size, and show that the model's comparative statics are robust to this more realistic assumption.

Third, in the implicit collusion scenario we assumed that collusion takes the form of "pseudo competition" in which the banks set their fees jointly with the goal of allocating firms to underwriters in a way that maximizes their combined profit. Another, more extreme, form of collusion is perfect price discrimination, under which underwriters are able to extract each firm's whole surplus from going public by setting firm-level fees in a way that makes only one bank a viable option for the firm's IPO. In Appendix D, we examine the implications of underwriters' ability to achieve perfect price discriminations for the relations between their proportional and absolute fees on one hand and the demand for public incorporationt on the other hand. The comparative statics and empirical predictions following from the model of perfect price

[4] Bain (1951) shows that it is easier to maintain collusion when the number of colluding firms is small. Barla (1998) demonstrates that it is harder to maintain tacit price coordination in the presence of large firm-size asymmetry.

discrimination are very different from those following from the model of implicit collusion in which underwriters pseudo-compete by setting fees jointly with the goal of allocating particular IPOs to particular underwriters.

# 3 Empirical tests

## 3.1 Data

We draw our IPO sample from the Securities Data Company (SDC) IPO database and supplement it by data on IPO underwriting spreads and underwriter reputation scores, provided to us by Jay Ritter. Following prior studies examining underwriting fees and IPO underpricing (e.g., Chen and Ritter (2000), Hansen (2001), and Abrahamson, Jenkinson and Jones (2011)), we exclude from our sample IPOs by banks and utilities, closed-end funds, REITs, ADRs, reverse LBOs, unit offerings, IPOs with offer price lower than \$5, and offerings that result from spinoffs. Finally, we require that the information on underwriting spread and post-IPO first-day return (IPO underpricing) be available.

IPOs are not the only possible way of obtaining public incorporation. An alternative is an acquisition of a privately-held firm by a publicly-traded one. Therefore, one of the measures of the demand for public incorporation that we construct is based not only on the number of IPOs but also on the number of acquisitions of private firms by public ones in a given year. We obtain our acquisitions sample from the SDC M&A database. We include in our sample acquisitions that satisfy the following two criteria. First, we only count acquisitions of relatively large private firms, for which an IPO would be a conceivable alternative to an acquisition by a public firm. Specifically, in each year we only consider acquisitions in which the target value is equal or larger to the equity value of the smallest IPO firm in that year. Second, since we are interested in firms that actively entertain the possibility of becoming public, we restrict our attention to acquisitions in which the merger is at least partially initiated by the target. In particular, we only consider private targets that hired an M&A advisor prior to acquisition.

Our final sample consists of 6,917 firm-commitment IPOs by U.S. firms between 1975 and 2013 and 3,443 acquisitions satisfying the two aforementioned restrictions. Our acquisitions sample spans years 1981 to 2013, as the coverage of M&As in SDC is sparse prior to 1981. Panel A of Table 1 presents summary statistics of the IPO and M&A market by calendar year.

Insert Table 1 here

The number of IPOs varies between 12 in 1975 and 603 in 1996. U.S. firms have raised more than \$600 billion (2010) dollars through IPOs during the 39 years of our sample. Annual

CPI-adjusted IPO proceeds also vary considerably throughout our sample period, ranging from \$0.5 billion in 1977 to \$57 billion in 1999. The early 1980s and the 1990s are the two hottest periods for IPOs. The number of acquisitions of relatively large private targets that hired an M&A advisor ranges between 27 in 1991 and 296 in 1998, while the annual value of acquisitions ranges between 2.9 billion in 1991 to 94 billion in 2000.

The first three columns of Panel B present statistics on annual underwriting spreads and IPO underpricing. Similar to past studies (e.g., Chen and Ritter (2000) and Hansen (2001)), the mean underwriting spread is 7.3% and has been on a declining trajectory over the last three decades. Mean underpricing, calculated as the percentage difference between the newly public stock's closing price at the first trading day and its offer price, is 15%. Mean annual underpricing varies over time, ranging from $-0.2\%$ for 12 IPOs underwritten in 1975 to 72% for 397 IPOs underwritten in 1999. Consistent with past studies (e.g., Ljungqvist and Wilhelm (2003) and Loughran and Ritter (2004)), underpricing tends to be positively correlated with the demand for public incorporation: The correlation between mean annual underpricing and annual number of IPOs is 45%. Since it is conceivable that underwriters receive indirect compensation from IPO investors only when underpricing is positive, the next column presents weighted average underpricing, in which we winsorize IPO-level underpricing at zero.

The next four columns of Panel A present annual IPO statistics. In particular, in a typical year, 39% of IPOs are backed by venture capital funds, 44% of IPOs are by firms in the hi-tech sector, 18% of IPO proceeds are secondary, and 20% of IPOs are syndicated, i.e. involve multiple book runners. The percentage of IPOs that involve multiple book runners is increasing over time: There are no syndicated IPOs up to year 1992, while in each of the last five years of the sample, more than 80% of IPOs are syndicated. This finding is consistent with Hu and Ritter (2007), who document an increasing trend in the proportion of IPOs with multiple book runners.

The last four columns in Panel B present annual proportions of IPOs underwritten by banks of relatively high quality. In particular, we use two measures of underwriter quality:

1) $QualityCM_{i,t}$ is based on the underwriter reputation score, first proposed by Carter and Manaster (1990) and extended by Loughran and Ritter (2004). The highest score, 9, is given to a total of 15 most reputable underwriters throughout the sample period, including Goldman Sachs, Morgan Stanley, Merrill Lynch, JP Morgan, Deutsche Bank, Citigroup, and Credit Suisse. The next set of underwriters, with scores ranging from 8 to 9 includes UBS, Wells Fargo, Smith-Barney, and Oppenheimer among others. We define banks with a reputation score of 8 or above in a given year as high-quality underwriters, and banks with lower scores

as low-quality underwriters. The mean number of underwriters with the score equal or higher than 8 in a given year is 15 and the median is 14.

2) $QualityMS_{i,t}$ is based on Beatty and Welch (1996), who argue that banks' past shares of the underwriting market are related to their current quality – reputable underwriters are those that have done more deals in the past. To smooth historical underwriting volume in a parsimonious fashion, we follow Beatty and Welch (1996) and apply exponentially declining coefficients to IPOs underwritten by a given bank: $Q_{i,t} = \sum_{\tau=t-5}^{t-1} 2^{-\frac{(t-\tau)}{5}} Vol_{i,\tau}$, where $Q_{i,t}$ is the quality index of underwriter $i$ in year $t$ and $Vol_{i,\tau}$ is the volume of IPOs underwritten by bank $i$ in year $\tau$. IPOs underwritten in the past year get the coefficient of 0.87, and offerings 2/3/4/5 years old have coefficients 0.76/0.66/0.57/0.50 respectively. Underwriter $i$'s market share in year $t$ is computed as $\mathrm{S}_{i,t} = \frac{Q_{i,t}}{\sum_j Q_{j,t}}$ where $j$ indexes all underwriters active in year $t$. We then rank underwriters each year by their past market shares. To be consistent with the annual number of underwriters classified as high-quality ones based on Carter and Manaster (1990) measure, we define underwriters having top-15 past market shares as high-quality ones and others as low-quality ones.

In Panel C of Table 1 we report additional statistics for the variables described above. The standard deviation of underwriting spread is about 1% and the median is exactly 7%, consistent with the clustering pattern documented by Chen and Ritter (2000). In contrast, there is significant variation in IPO underpricing. The standard deviation of underpricing across $6,917$ IPOs is 39%.

Our model shows that the comparative statics of underwriter compensation with respect to the demand for public incorporation may depend on underwriter quality. Panel D of Table 1 presents statistics on the number and volume of IPOs underwritten by banks of various quality, as proxied by the Carter-Manaster reputation score. If an IPO had multiple book runners – 676 deals in our sample involve two to eleven book runners – we divide issue proceeds evenly by the number of book runners and count this IPO multiple times. 27% of all underwriter-years belong to the high-quality underwriter subsample based on the Carter and Manaster (1990) measure. Banks with reputation scores equaling or exceeding 8 underwrite 57% of all deals in our sample in terms of numbers and 85% in terms of value. IPOs underwritten by high-quality banks tend to be larger: there is an almost perfect monotonic relation between underwriter reputation score and mean value of IPO proceeds, as follows from the last column in Panel D. This is consistent with the assortative matching result in the model and the evidence in Akkus, Cookson and Hortacsu (2015).

### 3.2 Testing the implicit collusion hypothesis versus the oligopolistic competition hypothesis

#### 3.2.1 Testing Prediction 1

Prediction 1 concerns the relation between the weighted average proportional underwriter compensation and the demand for public incorporation. Under the oligopolistic competition hypothesis, this relation is expected to be positive. Under the implicit collusion hypothesis, the relation for high-quality underwriters is expected to be positive as well, but for low-quality underwriters the relation is expected to be U-shaped. To test these predictions, we estimate the following regression:

$$\begin{aligned} Avg\_comp_{i,t} = \alpha + \beta_1(Dem\_pub_t * HQ_{i,t}) + \beta_2(Dem\_pub_t^2 * HQ_{i,t}) + \\ \beta_3(Dem\_pub_t * LQ_{i,t}) + \beta_4(Dem\_pub_t^2 * LQ_{i,t}) + \overrightarrow{\theta}\,\overrightarrow{X_{i,t}} + \varepsilon_{i,t}. \end{aligned} \tag{23}$$

Bank $i$'s proportional compensation for underwriting IPO of firm $j$ in year $t$, $Comp_{i,j,t}$, consists of a direct component and, possibly, an indirect one. The direct component is the proportional underwriting fee (gross spread) paid to the underwriter by the issuing firm. We consider a certain percentage of IPO underpricing as the indirect component of underwriter compensation, following evidence that suggests that institutional investors in IPOs indirectly reward underwriters for allocating underpriced IPO shares to them. For example, Reuter (2006) finds a positive relation between trading commissions paid by a mutual fund family to an underwriter and the fund family's holdings of recent profitable IPO shares allocated by that underwriter, and interprets this finding as consistent with underwriters profiting from discretionary allocations of IPO shares. Nimalendran, Ritter, and Zhang (2007) find abnormally intensive trading in the 50 most liquid stocks before allocations of significantly underpriced IPO shares and suggest that institutional investors trade liquid stocks to generate excessive commissions to underwriters in order to get favorable allocations of underpriced IPO shares.

There is no consensus regarding the proportion of IPO underpricing that is captured by the underwriters, and the estimates vary widely. Goldstein, Irvine, and Puckett (2011) examine the share of IPO underpricing that is returned to underwriters in the form of increased trading commissions and estimate that on average, lead underwriter receives between 2 and 5 cents in abnormal commission revenue for every \$1 left on the table. Nimalendran, Ritter, and Zhang (2007) suggest that this proportion ranges between 30% and 65%, based on the Credit Swiss First Boston's settlement in 2001 of a federal investigation of alleged abuses in its distribution of IPO shares. Kang and Lowery (2014) estimate similar fraction of IPO underpricing that accrues to IPO underwriters within a structural model of IPO price setting.

While in the model we tread underwriting spread and the proportion of underpricing accruing to underwriters together, in reality there is an important difference between the two types of underwriter compensation. Unlike the underwriting fee, which is set in advance of an IPO, underpricing is observed during post-IPO trading and, thus, incorporates information revealed during the IPO process. Therefore, realized underpricing may be a biased measure of ex-ante expected underpricing. Thus, while it is useful to include various proportions of underpricing in a measure of overall underwriter compensation, it is also important to examine the robustness of the results to the specification in which underwriter compensation consists of only the direct component – IPO spread, which is not subject to measurement error. As a result, our measures of underwriter compensation are computed as follows.

$Direct\&indirect\_comp_{i,j,t}$ is the combination of IPO spread and a certain proportion of IPO underpricing, where we vary this proportion between 0% an 65%. We winsorize underpricing at zero, as it is reasonable to assume that underwriters capture a share of IPO underpricing only when the latter is positive. In addition, we winsorize underpricing at 195%, which corresponds to top 1% of first-day returns.[5]

$Avg\_comp_{i,t}$ is the weighed average proportional compensation (direct and/or indirect) of underwriter $i$ in year $t$, computed as the ratio of the sum of dollar underwriting spread and a proportion of dollar underpricing of all IPOs underwritten by bank $i$ in year $t$ on one hand to the sum of dollar value of underwritten IPOs by that bank in that year on the other hand.

$Dem\_pub_t$ is the demand for public incorporation. We use two proxies for the demand for public incorporation. The first proxy is $\#IPO_t * 0.01$, which is the annual number of IPOs in year $t$ multiplied by 0.01. Multiplying $\#IPO_t$ by 0.01 conveniently scales regression coefficients. As we show in Lemma 6, in the model in which an IPO is the only method of obtaining public incorporation, the equilibrium number of underwritten IPOs is increasing in the demand for public incorporation, i.e. in the number of firms considering going public. Our second proxy for the demand for public incorporation accounts for the fact that an IPO is not the only method of obtaining public incorporation. Private firms may become public after being acquired by publicly-traded ones. This proxy is computed as $(\#IPO_t + \#Acq_t) * 0.01$, which is the annual combined number of IPOs in year $t$ and the number of acquisitions by public bidders of private targets belonging to our restricted sample in year $t$, multiplied by 0.01.

[5]The results are robust to not winsorizing underpricing at zero and to winsorizing it at the top 5% level instead of the top 1% level.

$HQ_{i,t}$ and $LQ_{i,t}$ are high-quality and low-quality underwriter dummies. In particular, we define high quality indicator variables, $HQ(CM)_{i,t}$ and $HQ(MS)_{i,t}$ that correspond to the Carter-Manaster and Beatty-Welch measures of underwriter quality respectively. The regression in (23) is estimated at the underwriter-year level.[6]

We follow Hansen (2001), Torstila (2003), and Abrahamson, Jenkinson and Jones (2011) in defining the vector of control variables, $\overrightarrow{X_{i,t}}$, in (23). It includes weighted average values across all IPOs underwritten by bank $i$ in year $t$ of the following variables: IPO size, measured as the natural logarithm of the issue proceeds, i.e. of the product of the number of shares offered by firm $j$ in its IPO and the final offer price, winsorized at the top 1% of its distribution;[7] the percentage of secondary shares in the offering; hi-tech indicator equaling one if the issuing firm operates in the hi-tech sector, as defined in Loughran and Ritter (2004); VC indicator equaling one if the issue is backed by a venture capital fund; and syndicate indicator that equals one if there are multiple book runners in the issue. We estimate the regressions using OLS and cluster standard errors at the underwriter level.

Both the implicit collusion and oligopolistic competition hypotheses predict a positive relation between underwriter compensation and the demand for public incorporation for high-quality underwriters. Thus, both hypotheses predict that: $\beta_1 > 0$ and/or $\beta_2 > 0$, and in case that either $\beta_1 < 0$ or $\beta_2 < 0$ the relation is expected to be positive in the range of the relevant values of the measure of the demand for public incorporation, $\#IPO_t * 0.01$ or $(\#IPO_t + \#Acq_t) * 0.01$.[8] However, the two hypotheses lead to different predictions for low-quality banks: the oligopolistic competition hypothesis predicts a positive relation between underwriter compensation and the demand for public incorporation, while the implicit collusion hypothesis predicts a U-shaped relation ($\beta_3 < 0$, $\beta_4 > 0$, and the inflection point of the relation,

[6]The specification in (23) restricts the coefficients on the control variables to be the same for high-quality and low-quality underwriters. An alternative specification, in which we run the regression

$$Avg\_comp_{i,t} = \alpha + \beta_1(Dem\_pub_t) + \beta_2(Dem\_pub_t^2) + \overrightarrow{\theta}\,\overrightarrow{X_{i,t}} + \varepsilon_{i,t},$$

separately for subsamples of high-quality and low-quality underwriters produces similar results.

[7]In computing the IPO proceeds, we follow Ellis, Michaely and O'Hara (2000) and include the over-allotment option. If the over-allotment option is exercised, IPO proceeds and underwriter's compensation increase. Underwriters tend to exercise this option if the aftermarket price is higher than the offer price. We obtain from SDC the information about whether an underwriter was given the over-allotment option (that typically equals 15% of the shares issued in the IPO) and to what extent this option was exercised.

[8]In the latter case, if $\beta_1 > 0$ and $\beta_2 < 0$, we expect the inflection point, $-\beta_1/(2\beta_2)$ to be above the highest value of $\#IPO_t * 0.01$ ($(\#IPO_t + \#Acq_t) * 0.01$), which equals 6.03 (8.22); and if $\beta_1 < 0$ and $\beta_2 > 0$, we expect the inflection point to be below the lowest value of $\#IPO_t * 0.01$ ($(\#IPO_t + \#Acq_t) * 0.01$), which is 0.12 (0.74).

$-\beta_3/(2\beta_4)$, within the relevant range of the independent variable: $0.12 < \#IPO_t * 0.01 < 6.03$ or $0.74 < (\#IPO_t + \#Acq_t) * 0.01 < 8.22$).

The results of estimating (23) are reported in Table 2. Panel A reports the results in which the measure of the demand for public incorporation is $\#IPO_t * 0.01$, while Panel B presents results in which the measure is $(\#IPO_t + \#Acq_t) * 0.01$. In the first five columns we define high-quality underwriters according to $QualityCM_{i,t}$, whereas in columns 6-10, high-quality underwriters are defined according to $QualityMS_{i,t}$.

Insert Table 2 here

In Panel A, the results for low-quality underwriters support the implicit collusion hypothesis and are inconsistent with the competition hypothesis. The coefficients on the linear term of the demand for public incorporation $(\#IPO_t * 0.01) * LQ_{i,t}$ are negative and significant in all ten specifications, while the coefficients on the quadratic term of the demand for public incorporation, $(\#IPO_t * 0.01)^2 * LQ_{i,t}$, are positive and highly significant in all specifications. The inflection point in all specifications ranges between 1.56 and 2.54, which is within the range of $\#IPO_t * 0.01$ (0.12 to 6.03), and is close to the mean value of $\#IPO_t * 0.01$, which equals 1.78, suggesting a U-shaped relation between the demand for public incorporation and the proportional compensation of low-quality underwriters.

The relations between the proportional compensation of high-quality underwriters and the linear and quadratic terms of the demand for public incorporation are insignificant: the coefficient on the linear term, $\beta_1$ is insignificantly positive in all ten specifications, while the coefficient on the quadratic term, $\beta_2$ is insignificantly negative in the regressions in which only the direct component of underwriter compensation is considered and tends to be positive in the regressions in which underwriter compensation accounts for a positive fraction of underpricing accruing to underwriters. Among cases in which indirect underwriter compensation is considered, in the only specification in which $\beta_2$ is negative, the inflection point of 12.23 is above the highest value of $\#IPO_t * 0.01$ (6.03), suggesting an overall positive, albeit statistically insignificant, relation between the proportional compensation of high-quality underwriters and the demand for public incorporation.

The coefficients on control variables are generally consistent with past literature: average IPO size is negatively related to proportional underwriter compensation; banks underwriting larger proportions of secondary offerings and VC-backed offerings receive lower proportional compensation; banks focusing on high-tech IPOs tend to receive higher average proportional compensation; and compensation in syndicated IPOs tends to be larger ceteris paribus.

The results in Panel B are generally consistent with those in Panel A. For low-quality underwriters, the relation between weighted average proportional underwriter compensation and the demand for public incorporation, proxied by the combined annual number of IPOs and acquisitions of private firms that hired an M&A advisor, is U-shaped. The coefficients on the linear term of $(\#IPO_t + \#Acq_t) * 0.01$ are negative in all ten specifications and are significant in nine specifications out of ten. The coefficients on the quadratic term, $(\#IPO_t + \#Acq_t)^2 * 0.01$, are positive in all ten specifications and are significant at 1% level in eight of them. The inflection point in all specifications ranges between 1.58 and 4.59, which is inside the range of $(\#IPO_t + \#Acq_t) * 0.01$ (0.74 to 8.22).

For high-quality underwriters, the relation between proportional underwriter compensation and the demand for public incorporation tends to be positive. The coefficients on the linear term of $(\#IPO_t + \#Acq_t) * 0.01$ are generally insignificant, but are positive in eight specifications out of ten. The coefficients on the quadratic term are positive and significant in eight specifications. In cases in which underwriter compensation measure includes an indirect component and the signs of $\beta_1$ and $\beta_2$ are different, the inflection points, ranging between 0.07 and 0.18, are below the lower bound of the range of $(\#IPO_t + \#Acq_t) * 0.01$, suggesting a positive relation between high-quality underwriters' proportional compensation and the demand for public incorporation. Overall, the results in Table 2 tend to be consistent with the implicit collusion hypothesis, as the relation between proportional underwriter compensation and the state of the IPO market is U-shaped for lower-quality underwriters and tends to be positive for higher-quality banks.

### 3.2.2 Testing Prediction 2

Prediction 2 concerns the relation between the ratio of average absolute (dollar) compensation received by high-quality underwriters to average absolute compensation received by low-quality ones, on one hand, and the demand for public incorporation, on the other hand. To test this prediction, we estimate the following regression:

$$\log\left(\frac{Avg\_\$Comp_{i\in HQ,t}}{Avg\_\$Comp_{j\in LQ,t}}\right) = \alpha + \beta_1 Dem\_pub_t + \beta_2 Dem\_pub_t^2 + \overrightarrow{\theta}\,\overrightarrow{X_{i,j,t}} + \varepsilon_{i,j,t}. \qquad (24)$$

The dependent variable in (24) is the natural logarithm of the ratio of the following two quantities. The numerator is the weighted average dollar compensation of high-quality underwriter $i$ in year $t$, $Avg\_\$Comp_{i\in HQ,t}$. It is computed as the ratio of the total underwriting fees, including the over-allotment option, and the proportion of dollar underpricing of IPOs underwritten by bank $i$ in year $t$ on one hand, to the number of IPOs underwritten by bank $i$ in year $t$ on the other hand. The denominator, $Avg\_\$Comp_{j\in LQ,t}$, is the weighted average dollar compensation per IPO of low-quality underwriter $j$ in year $t$, computed similarly.

We take the logarithm of the dependent variable because of its high skewness. Similar to tests in Table 2, $Dem\_pub_t$ refers to either $\#IPO_t * 0.01$ or $(\#IPO_t + \#Acq_t) * 0.01$, and underwriter quality is measured based on the underwriter's Carter and Manaster (1990) score or Beatty and Welch (1996) measure. The control variables are based on those in (23) and are measured as the differences between the underwriter-year average of the respective variable for a high-quality underwriter (e.g., logarithm of IPO proceeds) and the underwriter-year average of that variable for a low-quality underwriter. The unit of observation in (24) is HQ-LQ underwriter pairs, i.e. all combinations of high-quality and low-quality underwriters. The standard errors are clustered at the level of each high-quality underwriter.

The oligopolistic competition model predicts a negative relation between the demand for public incorporation and the ratio of high-quality underwriter's dollar compensation to that of low-quality underwriter, i.e. $\beta_1 < 0$ and/or $\beta_2 < 0$, and in case that either $\beta_1 > 0$ or $\beta_2 > 0$ the relation is predicted to be negative in the relevant range of the demand for public incorporation measure. The implicit collusion model predicts a hump-shaped relation, i.e. $\beta_1 > 0$, $\beta_2 < 0$, and the inflection point of the relation, $-\beta_1/(2\beta_2)$, is expected to be within the relevant range of the demand for public incorporation. Similar to Table 2, Panel A of Table 3 presents results of tests in which the demand for public incorporation is proxied by $\#IPO_t * 0.01$, while in Panel B it is proxied by $(\#IPO_t + \#Acq_t) * 0.01$.

The results of estimating (24) are presented in Table 3.

Insert Table 3 here

In Panel A, the results are consistent with the implicit collusion hypothesis and are inconsistent with the oligopolistic competition hypothesis. In particular, in all ten specifications, the coefficients on $\#IPO_t * 0.01$ ($\beta_1$) are positive and highly significant. The coefficients on $\#IPO_t^2 * 0.01$ ($\beta_2$) are negative in all specifications and are significant in nine cases out of ten. In all specifications, the inflection point of the hump-shaped relation lies inside the range of values of $\#IPO_t * 0.01$ (between 0.12 and 6.03), and is closer to the upper end of the range of $\#IPO_t * 0.01$, suggesting that the relation between the ratio of compensation of high-quality banks to that of lower-quality ones on one hand and the demand for public incorporation on the other hand is positive for the most part and becomes negative only in relatively high states of the IPO market. This result is inconsistent with the oligopolistic competition hypothesis, which predicts a negative relation for all states of the IPO market.

The results in Panel B are even stronger than those in Panel A. The coefficients on $\#IPO_t * 0.01$ are positive and highly significant, while the coefficients on $\#IPO_t^2 * 0.01$ are negative and highly significant in all specifications. The inflection point of the implied hump-shaped relation ranges between 5.83 and 8.05, both in the range of the annual combined number of IPOs and acquisitions of private firms.

Overall, the results in Tables 2 and 3 tend to be consistent with the implicit collusion hypothesis. Notably, our results suggest that potential collusion among underwriters is unlikely to take the form of implicit price discrimination. The reason is that a model of implicit price discrimination results in a negative relation between the ratio of dollar compensation of high-quality banks to that of lower-quality banks and the demand for public incorporation, as we show in Appendix D, which is inconsistent with the empirical results in Table 3.

#### 3.2.3 Robustness tests

This section discusses the results of various robustness tests. These results are not tabulated for brevity and are included in the Internet Appendix.

**Tests using a subsample of the largest underwriters**

As mentioned above, it is conceivable that larger (higher-quality) underwriters cooperate in setting IPO fees, while competing with smaller (lower-quality) underwriters. We show in Appendix B that the predictions of the two versions of the model hold within a subset of colluding underwriters, even in the presence of other, non-colluding, ones. To examine this possibility empirically, we test the predictions of the two versions of the model, while concentrating on a sample that consists of underwriters with Carter-Manaster (1990) reputation score equal or higher than 3 in a given year, with the idea that these banks are ex-ante more likely to cooperate in deciding on compensation for IPO underwriting.

The results of estimating (23) for the subsample of more reputable banks are generally consistent with those in Table 2. In particular, the coefficients on $\#IPO_t * 0.01 * LQ_{i,t}$ are significantly negative, and the coefficients on $\#IPO_t * 0.01^2 * LQ_{i,t}$ are significantly positive, with the inflection point of the relation ranging between 1.05 and 2.91, i.e. within the range of $\#IPO_t * 0.01$. The results of tests in which the measure of the demand for public incorporation is $(\#IPO_t + \#Acq_t) * 0.01$ are generally similar.

The results of estimating the relation between the ratio of high-quality banks' dollar compensation to that of low-quality banks on one hand and the demand for public incorporation on the other hand, as in (24), using the restricted sample of underwriters, also support the implicit collusion hypothesis. In some cases the results are stronger than the full-sample results reported in Table 3, as follows from the magnitudes of the positive coefficients on

$\#IPO_t * 0.01$ and $(\#IPO_t + \#Acq_t) * 0.01$ and the negative coefficients on $(\#IPO_t * 0.01)^2$ and $((\#IPO_t + \#Acq_t) * 0.01)^2$, and are inconsistent with the oligopolistic competition hypothesis.

**Tests using different measures of underwriter quality**

Our cutoffs of high and low underwriter quality are arguably arbitrary. Thus, we examine the robustness of our results to underwriter quality definitions. In particular, we define high underwriter quality in the following alternative ways:

1) Carter-Manaster (1990) score equal or higher than 9;

2) Carter-Manaster (1990) score higher than 7;

3) Top 5 rank of Beatty and Welch (1996) lagged market share measure;

4) Top 10 rank of Beatty and Welch (1996) lagged market share measure.

The results of estimating the regressions in (23)–(24) for each of the alternative cutoffs of underwriter quality are fully consistent with the baseline results reported in Tables 2 and 3.

**Tests addressing multiple book runners in an IPO**

Our model abstracts from one important feature of the underwriting market – the prevalence of IPOs underwritten by multiple book runners, especially in recent years (see Table 1). The fact that underwriters tend to form syndicates now much more than in the past does not necessarily suggest that they also collude more than previously in setting IPO fees and prices. The reason is that collusion refers to coordination across IPOs, not within a single IPO. However, syndication may affect underwriters' incentives to implicitly collude in setting IPO fees and prices (e.g., Corwin and Schultz (2005)).

We examine whether our results are driven by joint book runners in two ways. First, we estimate the regressions in (23)–(24) within the sub-period 1975–2000. As evident from Table 1, there are almost no cases of multiple book runners in an IPO during that period. Second, we re-estimate (23)–(24) within the full sample, while considering an IPO as a unit of observation, i.e. treating an IPO underwritten by multiple banks as one observation. In these tests we measure underwriter quality by the quality of the lead underwriter, i.e. the first-listed book runner.

The results of both sets of tests are generally consistent with the baseline results in Tables 2-3 and with the implicit collusion hypothesis. In particular, the relation between the proportional underwriter compensation and the demand for public incorporation continues to be U-shaped for relatively low-quality underwriters, and the relation between the ratio of high-quality underwriters' total compensation to that of low-quality banks continues to be hump-shaped in all specifications.

**Tests using a subsample with little clustering of IPO spreads**

For reasons outside of our model's scope, there is significant clustering of IPO underwriting spreads at the 7% level. This clustering is especially prevalent among medium-sized IPOs (between \$20 million and \$100 million) in the middle and later parts of our sample (years 1988-2013). To ensure that this clustering does not drive our empirical results, we re-estimate the regressions in (23)–(24) after excluding the aforementioned subsamples. The results of estimating (23) are somewhat weaker than the full-sample results in Table 2 (the coefficient on the linear term of the demand for public incorporation is negative in all specifications but tends to be insignificant), but are generally consistent with the full-sample results. The reduced statistical significance is due, to some extent, to smaller sample size. The results of estimating (24) are fully consistent with the full-sample results in Table 3. Overall, these results suggest that our findings are not driven by the clustering of IPO gross spreads.

**Tests accounting for information asymmetry**

As discussed above, indirect compensation of underwriters, which takes the form of kickbacks from investors in underpriced IPOs, is a substantial part of the overall underwriter compensation. In our model, indirect underwriter compensation (underpricing) and direct compensation (IPO gross spread) are interchangeable. In reality, underpricing and underwriting spread are set separately, and while there is significant clustering of gross spreads, the variation in IPO underpricing is large (see Panel B of Table 1). Thus, any empirical relation between estimated underwriter compensation and the demand for public incorporation is likely to be driven by the relation between underpricing and the demand for public incorporation. In order to attribute the non-monotonic relations between the proportional compensation of relatively low-quality underwriters and the ratio of dollar compensation of higher-quality underwriters to that of lower-quality ones on one hand and the demand for public incorporation on the other hand to implicit collusion among underwriters, we need to ensure that these relations do not follow from alternative theories of IPO underpricing.

Many such theories rely on the assumption of asymmetric information among issuers, underwriters, and investors. Various types of asymmetric information models, such as those based on winner's curse (e.g., Rock (1986)), those based on information revelation during the book-building process (e.g., Benveniste and Spindt (1989) and Benveniste and Wilhelm (1990)), those based on agency conflicts (e.g., Baron (1982) and Biais, Bossaerts and Rochet (2002)), and those based on signaling (e.g., Allen and Faulhaber (1989), Grinblatt and Hwang (1989), and Welch (1989)) imply that there is a positive relation between the uncertainty about an IPO firm valuation and underpricing (e.g., Ritter (1984) and Beatty and Ritter (1986)). To the extent that the proportion of informed investors, who help reduce valuation uncertainty, is lower when the demand for public incorporation is high, information-asymmetry-based models are consistent with a positive relation between underpricing and the demand for public incorporation. [9]

Thus, the asymmetric-information-based theories of IPO underpricing translate into a prediction of a positive relation between underwriter's proportional compensation and the demand for public incorporation. This prediction is consistent with the prediction following from the oligopolistic competition setting in our model. It does not seem to be consistent, however, with the non-monotonic relation in the implicit collusion model and with the empirical relation documented in Table 2. However, to ensure that our results are not due to asymmetric information, we augment our tests of Predictions 1 and 2 by the following two industry-level information asymmetry measures: the mean number of analysts following firms in each of the Fama and French (1997) 49 industries in a given year, and the standard deviation of analysts' forecasts of firms' earnings, averaged within each Fama and French (1997) 49 industry in a given year. The results of these tests are fully consistent with the baseline results reported in Tables 2 and 3.

We conclude, therefore, that these alternative models of IPO underpricing cannot explain our empirical results,[10] which supports our interpretation of the results as consistent with implicit collusion among underwriters.

## 4 Conclusions

In this paper we try to shed light on an elusive question: Do IPO underwriters in the U.S. compete for IPO business by setting competitive spreads and offer prices? To answer this question, we construct two versions of a model of interaction between heterogeneous IPO underwriters and heterogenous firms. In the first, a model of oligopolistic competition, each bank sets its fee for underwriting services separately, with the objective of maximizing its own profit, while

[9] Similar predictions follow from a behavioral model of informational cascades (e.g., Welch (1992)), according to which investors in earlier successful IPOs, which may lead to more successful future IPOs due to positive information in the former, may demand higher compensation in the form of underpricing. Thus, the average underpricing in periods in which the demand for public incorporation is high, which may coincide with informational cascades, is likely to be higher than that in which the demand for public incorporation is low.

[10] Other theories of IPO underpricing, such as those based on the lawsuit avoidance hypothesis (e.g., Ibbotson (1975)), price stabilization (e.g., Benveniste, Busaba and Wilhelm (1996)), tax reasons (e.g., Taranto (2003)), and corporate control (e.g., Brennan and Franks (1997)) do not seem to lead to predictions about the proportional and absolute compensation of banks of various quality on one hand and the demand for public incorporation on the other hand.

accounting for the optimal response of other underwriters. In the second, a model of implicit collusion, underwriters cooperate and set their fees with the goal of maximizing their joint profit.

The two versions of the model generate different comparative statics and empirical predictions regarding the effects of the demand for public incorporation on equilibrium compensation of underwriters of various quality. Unlike most existing studies of the underwriting market structure, which separately test the implications of either the implicit collusion hypothesis or the competition hypothesis, we examine both hypotheses simultaneously. We test the contrasting empirical implications of the competitive and collusive models using U.S. IPO data from 1975 to 2013. Most of our evidence lends support to the implicit collusion hypothesis and is less consistent with the oligopolistic competition hypothesis.

Our conclusion that underwriters do not compete fiercely in IPO price setting complements recent studies that provide indirect evidence on the lack of competition in the IPO underwriting market. Liu and Ritter (2011) argue that by differentiating their services, e.g., providing all-star analyst coverage, underwriters effectively mitigate the extent of price competition. Hu and Ritter (2007) show that IPOs underwritten by multiple book runners have become increasingly popular since the turn of the century. Syndication of book runners reduces coordination costs and makes implicit collusion more sustainable, as it may overcome the issue of the legality of side payments among underwriters. However, the short history of IPOs underwritten by joint book runners limits our ability to conduct meaningful time-series empirical tests of this phenomenon.

Overall, our results demonstrate that empirical tests of predictions that follow from industrial organization models of interactions among underwriters and between underwriters, issuing firms and investors may lead to better understanding of the competitive structure of the IPO underwriting market. While beyond the scope of this paper, it would be interesting to examine the model's predictions using data from non-U.S. markets with sufficient time-series IPO data, such as the U.K., Japan, and Canada, in order to test the claim that non-U.S. underwriting markets are more competitive than the U.S. underwriting market (e.g., Abrahamson, Jenkinson and Jones (2011)). In addition, our model could also be used to investigate the structure of other markets in which heterogeneous intermediaries interact with heterogeneous firms. Examples include the market for underwriting seasoned equity offerings and the market for M&A advising. Such analyses could shed light on whether market power of financial intermediaries impacts the cost of intermediation and its evolution over time (e.g., Philippon (2015)).

# 5 Appendix

# A Proofs

**Proof of Lemma 1**

Assume first that $\frac{\lambda_1}{\alpha_1} > \frac{\lambda_2}{\alpha_2}$.

Then the value of a firm that is indifferent between having its IPO underwritten by $B_1$ and remaining private is given by

$$V_i(1+\alpha_1) - \lambda_1 = V_i \Rightarrow V_i = \frac{\lambda_1}{\alpha_1}. \tag{25}$$

Similarly, the value of a firm that is indifferent between having its IPO underwritten by $B_2$ and remaining private is given by

$$V_i(1+\alpha_2) - \lambda_2 = V_i \Rightarrow V_i = \frac{\lambda_2}{\alpha_2}. \tag{26}$$

Since $\frac{\lambda_1}{\alpha_1} > \frac{\lambda_2}{\alpha_2}$, a firm remains private if $V_i \leq \frac{\lambda_2}{\alpha_2}$.

The value of a firm that is indifferent between having its IPO underwritten by $B_1$ and having its IPO underwritten by $B_2$ is given by

$$V_i(1+\alpha_1) - \lambda_1 = V_i(1+\alpha_2) - \lambda_2 \Rightarrow V_i = \frac{\lambda_1 - \lambda_2}{\alpha_1 - \alpha_2}. \tag{27}$$

Since $\frac{\lambda_1-\lambda_2}{\alpha_1-\alpha_2} - \frac{\lambda_1}{\alpha_1} = (\frac{\lambda_1}{\alpha_1} - \frac{\lambda_2}{\alpha_2})(\frac{\alpha_2}{\alpha_1-\alpha_2}) > 0$, a firm chooses to have its IPO underwritten by $B_1$ if $V_i > \frac{\lambda_1-\lambda_2}{\alpha_1-\alpha_2}$.

In the intermediate region, $\frac{\lambda_2}{\alpha_2} < V_i \leq \frac{\lambda_1-\lambda_2}{\alpha_1-\alpha 2}$, a firm's IPO is underwritten by $B_2$.

Assume now that $\frac{\lambda_1}{\alpha_1} \leq \frac{\lambda_2}{\alpha_2}$.

It follows from (25) and (26) that a firm remains private if $V_i \leq \frac{\lambda_1}{\alpha_1}$.

Since $\frac{\lambda_1-\lambda_2}{\alpha_1-\alpha_2} - \frac{\lambda_2}{\alpha_2} = (\frac{\lambda_1}{\alpha_1} - \frac{\lambda_2}{\alpha_2})(\frac{\alpha_2}{\alpha_1-\alpha_1}) \leq 0$, $B_2$ does not underwrite any IPOs, as any firm for which $V_i(1+\alpha_2) - \lambda_2 > V_i$, $V_i(1+\alpha_2) - \lambda_2 < V_i(1+\alpha_1) - \lambda_1$.

Therefore, a firm performs an IPO underwritten by $B_1$ if $V_i > \frac{\lambda_1}{\alpha_1}$.

**Proof of Lemma 2**

Consider first the case of oligopolistic competition.

Assume that in equilibrium, $\frac{\lambda_1^*}{\alpha_1} \leq \frac{\lambda_2^*}{\alpha_2}$. In this case, it follows from Lemma 1 that $B_2$ does not underwrite any IPOs and its profit is 0.

Assume that instead $B_2$ deviates from the assumed equilibrium strategy and chooses $\lambda_2 = \lambda_1^* \frac{\alpha_2}{\alpha_1} - \epsilon$, where $\epsilon \to 0$.

Then the firm with value $V_i = \frac{\lambda_1^* - \lambda_2}{\alpha_1-\alpha_2}$ would choose to have its IPO underwritten by $B_2$. Since the marginal cost of underwriting the first infinitesimal unit of IPO is 0, this is a profitable deviation.

Therefore, $\frac{\lambda_1^*}{\alpha_1} \leq \frac{\lambda_2^*}{\alpha_2}$ is not an equilibrium; an equilibrium has to satisfy $\frac{\lambda_2^*}{\alpha_2} < \frac{\lambda_1^*}{\alpha_1}$.

Now assume that in equilibrium $\frac{\lambda_1 - \lambda_2}{\alpha_1 - \alpha 2} \geq 1$.

Then, since $V_i \leq 1$, every firm would prefer to have its IPO underwritten by $B_2$, and $B_1$ would not underwrite any IPOs. A profitable deviation for $B_1$ would be to charge $\lambda_1 = \lambda_2 + \alpha_1 - \alpha_2 - \epsilon$, where $\epsilon \to 0$ given that the marginal cost of underwriting the first infinitesimal unit of IPOs is zero.

Thus, in equilibrium $\lambda_1^*$ would be such that $\frac{\lambda_1^* - \lambda_2^*}{\alpha_1 - \alpha 2} < 1$.

Consider now the case of implicit collusion.

Assume that in equilibrium, $\frac{\lambda_1^*}{\alpha_1} \leq \frac{\lambda_2^*}{\alpha_2}$, such that $B_2$ does not underwrite any IPOs.

Consider the change in the underwriters' combined revenue from reducing $\lambda_2$ and setting it equal to $\lambda_2 = \lambda_1^* \frac{\alpha_2}{\alpha_1} - \epsilon$, where $\epsilon \to 0$, such that $B_2$ underwrites an infinitesimal unit of IPO.

The equilibrium mass of IPOs underwritten by $B_1$ equals

$$N_{1_{Coll}} = \left(1 - \frac{\lambda_1^* - \lambda_2}{\alpha_1 - \alpha_2}\right) N. \tag{28}$$

The equilibrium mass of IPOs underwritten by $B_2$ equals

$$N_{2_{Coll}} = \left(\frac{\lambda_1^* - \lambda_2}{\alpha_1 - \alpha_2} - \frac{\lambda_2}{\alpha_2}\right) N. \tag{29}$$

Differentiating the combined revenue of the two underwriters with respect to $\lambda_2$ results in

$$\frac{\partial \left(N_{1_{Coll}} \lambda_1 + N_{2_{Coll}} \lambda_2\right)}{\partial \lambda_2} = \frac{\lambda_1^*}{\alpha_1 - \alpha_2} + \left(\left(-\frac{1}{\alpha_1 - \alpha_2} - \frac{1}{\alpha_2}\right) \lambda_2 + \left(\frac{\lambda_1^* - \lambda_2}{\alpha_1 - \alpha_2} - \frac{\lambda_2}{\alpha_2}\right)\right) = -2 \frac{\lambda_1^* \alpha_2 - \lambda_2 \alpha_1}{\alpha_1 - \alpha_2}. \tag{30}$$

The expression in (30) approaches zero as $\lambda_2 \to \lambda_1^* \frac{\alpha_2}{\alpha_1}$.

The change in underwriters combined cost as a result of $B_2$ underwriting an infinitesimal unit of IPO equals the difference between $B_1$'s marginal cost of underwriting the last unit of IPO, which equals $\frac{c_1}{N^k} N_{1_{Coll}}^2$ and $B_1$'s marginal cost of underwriting the first infinitesimal unit of IPO, which approaches 0.

Thus, the (negative) change in the two banks' combined revenue as a result of deviating from the equilibrium in which $B_2$ does not underwrite any IPOs, which approaches zero, is lower in absolute value than the strictly negative change in the two banks' combined underwriting cost. In other words, the benefit of deviating from the equilibrium in which $B_2$ does not underwrite any IPOs is higher than the cost of such deviation. As a result, in equilibrium, both $B_1$ and $B_2$ underwrite positive masses of IPOs. It follows that in equilibrium $\frac{\lambda_2^*}{\alpha_2} < \frac{\lambda_1^*}{\alpha_1}$ needs to be satisfied.

Simlar to the proof in the case of oligopolistic competition, if in equilibrium $\frac{\lambda_1^* - \lambda_2^*}{\alpha_1 - \alpha_2} \geq 1$ then $B_1$

would not underwrite any IPOs. This does not maximize the banks' combined profit as having $B_1$ underwrite the first infinitesimal unit of IPO both increases the marginal revenue and reduces the marginal cost of that IPO. Thus, in equilibrium $\lambda_1^*$ would be such that $\frac{\lambda_1^*-\lambda_2^*}{\alpha_1-\alpha 2} < 1$. Note that the conditions $\frac{\lambda_2^*}{\alpha_2} < \frac{\lambda_1^*}{\alpha_1}$ and $\frac{\lambda_1^*-\lambda_2^*}{\alpha_1-\alpha_2} < 1$ imply that the mass of IPOs underwritten by $B_2$ in equilibrium is $\frac{\lambda_1^*-\lambda_2^*}{\alpha_1-\alpha_2} - \frac{\lambda_2^*}{\alpha_2} = \frac{\frac{\lambda_1}{\alpha_1}-\frac{\lambda_2}{\alpha_2}}{(\alpha_1-\alpha_2)/\alpha_1} > 0$.

The rest of the proof follows from the indifference conditions (25)-(27) in the proof of Lemma 1.

**Proof of Lemma 3**

Subtracting the sum of the two banks' equilibrium profits in the oligopolistic competition scenario in (14) and (15), from the banks' combined equilibrium profit in the implicit collusion scenario in (21) results in:

$$\pi^*_{joint_{Coll}} - (\pi^*_{1_{Comp}} + \pi^*_{2_{Comp}}) = \frac{4N^3\Gamma_1 + 4N^{2+k}\Gamma_2 + N^{1+2k}\Gamma_3 + N^{3k}\Gamma_4}{2\Phi^2_{Comp}\Phi_{Coll}}, \tag{31}$$

where

$$\Gamma_1 = c_1c_2^2\,\alpha_1^4 + c_2^3\,\alpha_1^4 + 2c_1c_2^2\,\alpha_1^3\alpha_2 + 3c_1^2c_2\alpha_1^2\alpha_2^2 + 2c_1^3\alpha_2^4,$$
$$\Gamma_2 = (\alpha_1-\alpha_2)\left(c_2^2\,\alpha_1^4 + 2c_1c_2\,\alpha_1^3\alpha_2 + 3c_1^2\alpha_1^3\alpha_2 + 6c_1c_2\,\alpha_1^2\alpha_2^2 + 3c_1^2\alpha_1\alpha_2^3 + c_1^2\alpha_2^4\right),$$
$$\Gamma_3 = \alpha_2\,(\alpha_1-\alpha_2)^2\left(8c_2\,\alpha_1^3 + 4c_1\alpha_1^2\alpha_2 + 13c_2\alpha_1^2\alpha_2 + 16c_1\,\alpha_1\alpha_2^2 + 3c_1\alpha_2^3\right),$$
$$\Gamma_4 = \alpha_1\alpha_2^2\,(\alpha_1-\alpha_2)^3\,(4\alpha_1+5\alpha_2)\,.$$

$\Gamma_1$, $\Gamma_2$, $\Gamma_3$, and $\Gamma_4$ are positive. Therefore, the underwriters' combined equilibrium profit in the collusive scenario, $\pi^*_{joint_{Coll}}$, is larger than the sum of their equilibrium profits in the oligopolistic competition scenario, $\pi^*_{1_{Comp}} + \pi^*_{2_{Comp}}$.

**Proof of Lemma 4**

Under the assumption that a given bank $j$ charges the same fee $\lambda_j$ to all firms it underwrites, $\frac{\lambda_j}{V_j}$ is clearly decreasing in $V_i$. This negative relation holds for every $\lambda_j$, in equilibrium or off-equilibrium.

**Proof of Lemma 5**

The difference between the equilibrium weighted average proportional compensation of $B_1$ and that of $B_2$ is given by

$$\overline{RF_1^*} - \overline{RF_2^*} = \frac{\lambda_1^*\left(1-\frac{\lambda_1^*-\lambda_2^*}{\alpha_1-\alpha_2}\right)}{\int_{\frac{\lambda_1^*-\lambda_2^*}{\alpha_1-\alpha_2}}^{1} V dV} - \frac{\lambda_2^*\left(\frac{\lambda_1^*-\lambda_2^*}{\alpha_1-\alpha_2}-\frac{\lambda_2^*}{\alpha_2}\right)}{\int_{\frac{\lambda_2^*}{\alpha_2}}^{\frac{\lambda_1^*-\lambda_2^*}{\alpha_1-\alpha_2}} V dV}. \tag{32}$$

In the oligopolistic competition case, plugging $\lambda^*_{1_{Comp}}$ from (10) and $\lambda^*_{2_{Comp}}$ from (11) into (32) results in:

$$\overline{RF^*_{1_{Comp}}} - \overline{RF^*_{2_{Comp}}} = \frac{N^3\Psi_1 + N^{2+k}\Psi_2 + N^{1+2k}\Psi_3 + N^{3k}\Psi_4}{\Psi_5}, \tag{33}$$

where

$$\Psi_1 = 8c_1c_2\alpha_1^2\left(\alpha_1 - \alpha_2\right),$$

$$\Psi_2 = 2c_2\alpha_1\left(c_2\alpha_1\left(3\alpha_1^2 - 5\alpha_1\alpha_2 + 2\alpha_2^2\right) + c_1\alpha_2\left(8\alpha_1^2 - 12\alpha_1\alpha_2 + 4\alpha_2^2\right)\right),$$

$$\Psi_3 = \left(\alpha_1 - \alpha_2\right)\alpha_2\left(2c_1\alpha_2\left(3\alpha_1^2 - 4\alpha_1\alpha_2 + \alpha_2^2\right) + c_2\alpha_1\left(11\alpha_1^2 - 15\alpha_1\alpha_2 + 4\alpha_2^2\right)\right),$$

$$\Psi_4 = \left(\alpha_1 - \alpha_2\right)^2\alpha_2^2\left(3\alpha_1^2 - 5\alpha_1\alpha_2 + 2\alpha_2^2\right),$$

$$\Psi_5 = 2Nc_1\Big(2Nc_2\alpha_1 + N^k\left(2\alpha_1 - \alpha_2\right)\alpha_2\Big) + N^k\Big(Nc_2\ \alpha_1\left(3\alpha_1 - 2\alpha_2\right) + N^k\alpha_2\left(3\alpha_1^2 - 4\alpha_1\alpha_2 + \alpha_2^2\right)\Big).$$

$\Psi_1$, $\Psi_2$, $\Psi_3$, $\Psi_4$, and $\Psi_5$ are positive. Thus, $\overline{RF^*_{1_{Comp}}} - \overline{RF^*_{2_{Comp}}} > 0$.

In the implicit collusion case, plugging in $\lambda^*_{1_{Coll}}$ from (17) and $\lambda^*_{2_{Coll}}$ from (18) into (32) results in:

$$\overline{RF^*_{1_{Coll}}} - \overline{RF^*_{2_{Coll}}} = \frac{2(N^4\Psi_6 + N^{3+k}\Psi_7 + N^{2+2k}\Psi_8 + N^{1+3k}\Psi_9 + N^{4k}\Psi_{10})}{\Psi_{11}\Psi_{12}}, \tag{34}$$

where

$$\Psi_6 = 8c_1^2c_2^2(\alpha_1 - \alpha_2),$$

$$\Psi_7 = 2c_1c_2(\alpha_1 - \alpha_2)(7\alpha_2c_1 + 4\alpha_1c_2),$$

$$\Psi_8 = (\alpha_1 - \alpha_2)\left(7c_1^2\alpha_2^2 + c_1c_2\alpha_2(17\alpha_1 - 10\alpha_2) + 3c_2^2\alpha_1^2\right),$$

$$\Psi_9 = \alpha_2(\alpha_1 - \alpha_2)(c_1\alpha_2(9\alpha_1 - 7\alpha_2) + 2c_2\alpha_1(3\alpha_1 - 2\alpha_2)),$$

$$\Psi_{10} = \alpha_2^2(3\alpha_1 - 2\alpha_2)(\alpha_1 - \alpha_2)^2,$$

$$\Psi_{11} = 4Nc_1\Big(Nc_2 + N^k\alpha_2\Big) + 3N^k\Big(Nc_2\alpha_1 + N^k\alpha_2(\alpha_1 - \alpha_2)\Big),$$

$$\Psi_{12} = Nc_1\Big(4Nc_2 + 3N^k\alpha_2\Big) + 2N^k\Big(Nc_2\alpha_1 + N^k\alpha_2(\alpha_1 - \alpha_2)\Big).$$

$\Psi_6$, $\Psi_7$, $\Psi_8$, $\Psi_9$, $\Psi_{10}$, $\Psi_{11}$, and $\Psi_{12}$ are positive. Therefore, $\overline{RF^*_{1_{Coll}}} - \overline{RF^*_{2_{Coll}}} > 0$.

**Proof of Lemma 6**

Differentiating $N^*_{1_{Comp}}$, $N^*_{2_{Comp}}$, $N^*_{1_{Coll}}$, and $N^*_{2_{Coll}}$ in (12), (13), (19), and (20) respectively with respect to $N$ results in

$$\frac{\partial N^*_{1_{Comp}}}{\partial N} = \frac{N^k \alpha_1 \left(N^3 \Omega_1 + N^{2+k}\Omega_2 + N^{1+2k}\Omega_3 + N^{3k}\Omega_4\right)}{\Omega_5^2}, \tag{35}$$

$$\frac{\partial N^*_{2_{Comp}}}{\partial N} = \frac{N^k \alpha_1 \alpha_2 \left(N^3 \Omega_6 + N^{2+k}\Omega_7 + N^{1+2k}\Omega_8 + N^{3k}\Omega_9\right)}{\Omega_5^2}, \tag{36}$$

$$\frac{\partial N^*_{1_{Coll}}}{\partial N} = \frac{N^k \left(N^3 \Omega_{10} + N^{2+k}\Omega_{11} + N^{1+2k}\Omega_{12} + N^{3k}\Omega_{13}\right)}{2\Omega_{14}^2}, \tag{37}$$

$$\frac{\partial N^*_{1_{Coll}}}{\partial N} = \frac{N^{1+k} c_1 \alpha_2 \left(N^2 \Omega_{15} + N^{1+k}\Omega_{16} + N^{2k}\Omega_{17}\right)}{2\Omega_{14}^2}, \tag{38}$$

where

$$\Omega_1 = 4c_1 c_2^2 \alpha_1^2 k,$$

$$\Omega_2 = 2c_2\alpha_1(c_1\alpha_2(\alpha_2 + 4(\alpha_1 - \alpha_2)k) + c_2\alpha_1(2\alpha_1 - \alpha_2)),$$

$$\Omega_3 = \alpha_2(\alpha_1 - \alpha_2)(2c_1\alpha_2(2\alpha_1 - \alpha_2)k + c_2\alpha_1(8\alpha_1 - \alpha_2(k+2))),$$

$$\Omega_4 = \alpha_2^2(\alpha_1 - \alpha_2)^2(4\alpha_1 - \alpha_2),$$

$$\Omega_5 = 2Nc_1\Big(2Nc_2\alpha_1 + N^k\alpha_2(2\alpha_1 - \alpha_2)\Big) + N^k\Big(2Nc_2\alpha_1(2\alpha_1 - \alpha_2) + N^k\alpha_2\left(4\alpha_1^2 - 5\alpha_1\alpha_2 + \alpha_2^2\right)\Big),$$

$$\Omega_6 = 8c_1^2 c_2 \alpha_1 k,$$

$$\Omega_7 = 4c_1(c_1\alpha_2(2\alpha_1 - \alpha_2) + c_2\alpha_1(\alpha_1 + 2\alpha_1 k - 2\alpha_2 k)),$$

$$\Omega_8 = (\alpha_1 - \alpha_2)(c_2\alpha_1(2\alpha_1 - \alpha_2)k + 2c_1\alpha_2(\alpha_1(4-k)) - \alpha_2),$$

$$\Omega_9 = \alpha_2(\alpha_1 - \alpha_2)^2(4\alpha_1 - \alpha_2),$$

$$\Omega_{10} = c_1 c_2^2 \alpha_1 k,$$

$$\Omega_{11} = c_2\left(c_1\alpha_2(\alpha_2 + 2(\alpha_1 - \alpha_2)k) + c_2\alpha_1^2\right),$$

$$\Omega_{12} = (\alpha_1 - \alpha_2)(2c_2\alpha_1 + c_1 k\alpha_2),$$

$$\Omega_{13} = (\alpha_1 - \alpha_2)^2\alpha_2^2,$$

$$\Omega_{14} = Nc_1(Nc_2 + N^k\alpha_2) + N^k(Nc_2\alpha_1 + N^k(\alpha_1 - \alpha_2)\alpha_2),$$

$$\Omega_{15} = c_1 c_2 k,$$

$$\Omega_{16} = N^k c_2\alpha_2 + N^k c_2\alpha_1,$$

$$\Omega_{17} = N^{2k}\alpha_2(\alpha_1 - \alpha_2)(2-k).$$

$\Omega_1$–$\Omega_{17}$ are all positive. Thus, the partial derivatives in (35), (36), (37), and (38) are positive.

### Proof of Proposition 1

Differentiating the equilibrium weighted average proportional fee of $B_1$ in (22) in the case of oligopolistic competition, with respect to $N$ results in

$$\frac{\partial \overline{RF_{1_{Comp}}}^*}{\partial N} = \frac{2N^k\alpha_1^2(1-k)\left(N^2(2c_1c_2\left(2c_1\alpha_2^2+c_2\alpha_1^2\right))+N^{1+k}(4N^kc_1c_2\alpha_2\left(\alpha_1^2-\alpha_2^2\right))+N^{2k}((2c1+c2)(\alpha_1-\alpha_2)^2\alpha_2^2)\right)}{2Nc_1\left(2Nc_2\alpha_1+\alpha_2(2N^k\alpha_1-\alpha_2)\right)+N^k\left(Nc_2\alpha_1(3\alpha_1-2\alpha_2)+N^k\alpha_2\left(3\alpha_1^2-4\alpha_1\alpha_2+\alpha_2^2\right)\right)} > 0 \tag{39}$$

Differentiating the equilibrium weighted average proportional fee of $B_2$ in (22) with respect to $N$ results in

$$\frac{\partial \overline{RF_{2_{Comp}}}^*}{\partial N} = \frac{4N^kc_2\alpha_1^2\alpha_2^2(1-k)}{\left(4Nc_2\alpha_1+N^k\alpha_2(3\alpha_1-2\alpha_2)\right)^2} > 0. \tag{40}$$

**Proof of Proposition 2**

Differentiating the equilibrium weighted average proportional fee of $B_1$ in (22) in the case of implicit collusion, with respect to $N$ results in

$$\frac{\partial \overline{RF_{1_{Coll}}}^*}{\partial N} = \frac{2N^kc_1(1-k)(2N^2c_2\left(2c_1\alpha_2^2+c_2\alpha_1^2\right)+4N^{1+k}c_2\alpha_1\alpha_2(\alpha_1-\alpha_2)+N^{2k}(3\alpha_1-2\alpha_2)(\alpha_1-\alpha_2))}{\left(4N^2c_1c_2+4N^{k+1}c_1\alpha_2+3N^{k+1}c_2\alpha_1+3N^{2k}\alpha_1\alpha_2-3N^{2k}\alpha_2^2\right)^2} > 0. \tag{41}$$

Differentiating the equilibrium weighted average proportional fee of $B_2$ in (22) with respect to $N$ results in

$$\frac{\partial \overline{RF_{2_{Coll}}}^*}{\partial N} = \frac{2N^kc_1\alpha_2^2(1-k)\left(2N^2c_1c_2-N^{2k}\alpha_2(\alpha_1-\alpha_2)\right)}{\left(4N^2c_1c_2+3N^{k+1}c_1\alpha_2+2N^{k+1}c_2\alpha_1+2N^{2k}\alpha_1\alpha_2-2N^{2k}\alpha_2^2\right)^2}. \tag{42}$$

The denominator of (42) is positive. The numerator of (42) is negative when $N < \left(\frac{\alpha_2(\alpha_1-\alpha_2)}{2c_1c_2}\right)^{\frac{1}{2-2k}}$ and it is positive when $N > \left(\frac{\alpha_2(\alpha_1-\alpha_2)}{2c_1c_2}\right)^{\frac{1}{2-2k}}$.

**Proof of Proposition 3**

Differentiating $\frac{\lambda^*_{1_{Comp}}}{\lambda^*_{2_{Comp}}}$, using (10) and (11), with respect to $N$ results in

$$\frac{\partial\left(\frac{\lambda^*_{1_{Comp}}}{\lambda^*_{2_{Comp}}}\right)}{\partial N} = \frac{2N\alpha_2\left(2\alpha_1c_2+N^k\alpha_2(\alpha_1-\alpha_2)\right)}{4Nc_2\alpha_1+3N^k\alpha_1\alpha_2-2N^k\alpha_2^2} > 0. \tag{43}$$

**Proof of Proposition 4**

Differentiating $\frac{\lambda^*_{1_{Coll}}}{\lambda^*_{2_{Coll}}}$, using (17) and (18), with respect to $N$ results in

$$\frac{\partial\left(\frac{\lambda^*_{1_{Coll}}}{\lambda^*_{2_{Coll}}}\right)}{\partial N} = \frac{N^kc_1(\alpha_2-\alpha_1)(k-1)\left(2N^2c_1c_2-N^{2k}\alpha_2(\alpha_1-\alpha_2)\right)}{\left(2N^2c_1c_2+N^{k+1}c_1\alpha_2+N^{k+1}c_2\alpha_1+N^{2k}\alpha_1\alpha_2-N^{2k}\alpha_2^2\right)^2}. \tag{44}$$

The denominator of (44) is positive. The numerator of (44) is positive when $N < \left(\frac{\alpha_2(\alpha_1-\alpha_2)}{c2_1c_2}\right)^{\frac{1}{2-2k}}$ and it is negative when $N > \left(\frac{\alpha_2(\alpha_1-\alpha_2)}{c2_1c_2}\right)^{\frac{1}{2-2k}}$.

## B Multiple banks

In this Appendix we relax the assumption of two underwriters. Assume that there are $K$ banks sorted by their quality. Assume also that banks that belong to the set $\mathbb{C}$ collude, while others do not. Extending the model to the case of multiple underwriters results in the following optimization problems of the $K$ banks:

$$\pi_j = \max_{\lambda_j} \left( \lambda_j \left( N \left( \overline{V_j} - \underline{V_j} \right) \right) - \frac{c_j}{N^k} \left( N \left( \overline{V_j} - \underline{V_j} \right) \right)^2 \right) \ \forall \ B_j \notin \mathbb{C}, \tag{45}$$

$$\pi_{joint} = \max_{\lambda_j,\, j \in \mathbb{C}} \left( \sum_{j \in \mathbb{C}} \left( \lambda_j \left( N \left( \overline{V_j} - \underline{V_j} \right) \right) - \frac{c_j}{N^k} \left( N \left( \overline{V_j} - \underline{V_j} \right) \right)^2 \right) \right), \tag{46}$$

$$\underline{V_1} = \frac{\lambda_1 - \lambda_2}{\alpha_1 - \alpha_2} \text{ and } \overline{V_1} = 1,$$

$$\underline{V_j} = \frac{\lambda_j - \lambda_{j+1}}{\alpha_j - \alpha_{j+1}} \text{ and } \overline{V_j} = \frac{\lambda_{j-1} - \lambda_j}{\alpha_{j-1} - \alpha_j} \ \forall \ 1 < j < K,$$

$$\underline{V_K} = \frac{\lambda_K}{\alpha_K} \text{ and } \overline{V_K} = \frac{\lambda_{K-1} - \lambda_K}{\alpha_{K-1} - \alpha_K}.$$

Equation (45) describes the problem of a bank that is not part of a set of colluding banks ($\mathbb{C}$), while equation (46) describes the problem of colluding banks, whose goal is to maximize their joint profit.

In what follows, we examine the case of three underwriters. In particular, we focus on three scenarios:

1) all three underwriters compete ("competition");

2) two highest-quality underwriters collude and they compete with the third underwriter ("partial collusion");

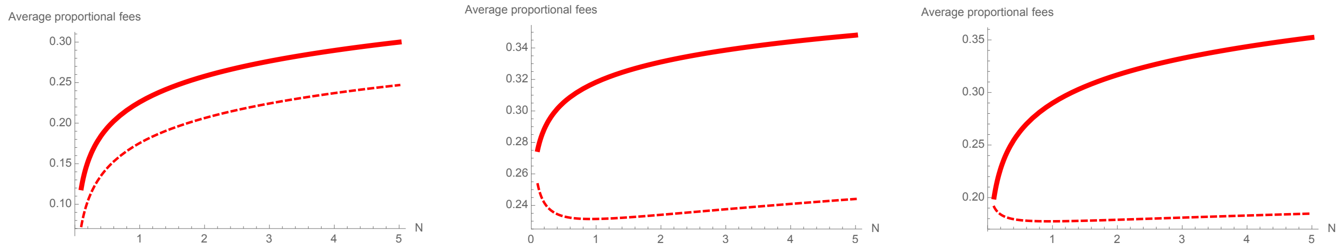
3) all three underwriters collude ("full collusion").

Figures 1–2 present comparative statics of average proportional fees and absolute fees of the two higher-quality banks, $B_1$ and $B_2$, for the three scenarios described above. The parameter values used in Figures 1 and 2 are: $\alpha_1 = 0.5$, $\alpha_2 = 0.3$, $\alpha_3 = 0.1$, $c_1 = 0.1$, $c_2 = 0.1$, $c_3 = 0.1$, $k = 0.5$.[11] Figure 1 presents weighted average proportional fees of the top two banks: solid lines depict the average proportional fee of $B_1$, while dashed lines correspond to the average proportional fee of $B_2$. Figure 1 demonstrates that the relation between the highest-quality bank's average proportional fee and the demand for public incorporation is positive in the competitive scenario and in (fully and partially) collusive scenarios. On the other hand, the relation between the average proportional fee of the medium-quality bank exhibits a positive relation with the demand for public incorporation in the competitive scenario and a U-shaped

[11] The shapes of the figures are robust to changes in parameter values.

**Figure 1: Average proportional fees: The case of three banks**

Figure 1A: Competitive case Figure 1B: Partially collusive case Figure 1C: Fully collusive case

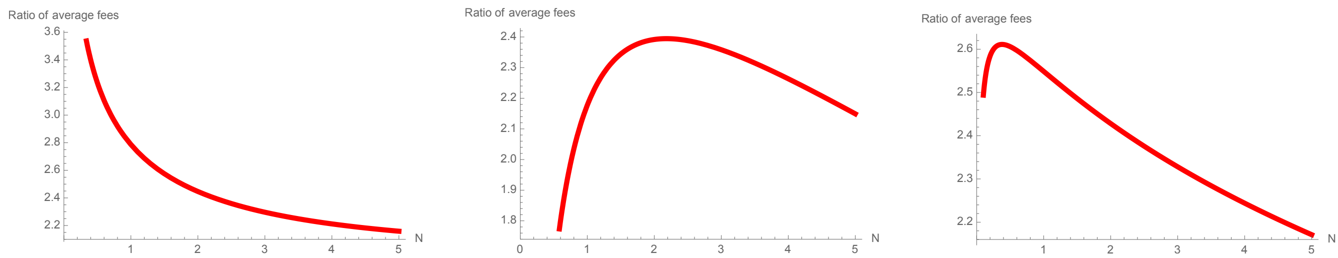



relation in the fully and partially collusive scenarios, consistent with the baseline results for two underwriters.

Figure 2 presents the relation between the ratio of the top two banks' absolute (dollar) fees under the three scenarios discussed above. It follows from Figure 2 that, similar to the two-bank case, the relation between the ratio of the two largest banks' absolute fees and the demand for public incorporation is negative when these two banks compete and it exhibits a hump-shaped relation with $N$ when the two banks collude, regardless of whether they collude with the third bank or compete with it. Overall, the numerical analysis in this section demonstrates that the comparative statics in our baseline model are robust to an inclusion of an additional, third, underwriter and, in general, are unlikely to be driven by the assumption of two underwriters.

**Figure 2: Ratio of absolute fees: The case of three banks**

Figure 2A: Competitive case Figure 2B: Partially collusive case Figure 2C: Fully collusive case




# C Optimal variable underwriting fees

In this Appendix we solve numerically a model in which we allow each of the two underwriters to choose not only the fixed component of its fee, but also its variable component, i.e. we now assume the following structure for bank $j$'s fee: $F_{i,j} = \lambda_j + \mu_j V_i$. For a given combination of $\lambda_1$, $\lambda_2$, $\mu_1$, and $\mu_2$ we compute using fine grid (of size $G = 0.01$) the optimal strategy of each firm whose value belongs to an interval $(0,1]$:

$$\begin{aligned}
&\text{remain private if } V_i(1+\alpha_1)-\lambda_1-\mu_1 V_i \le V_i \text{ and } V_i(1+\alpha_2)-\lambda_2-\mu_2 V_i < V_i,\\
&\text{IPO underwritten by } B_1 \text{ if } V_i(1+\alpha_1)-\lambda_1-\mu_1 V_i > \max\left\{V_i(1+\alpha_2)-\lambda_2-\mu_2 V_i, V_i\right\},\\
&\text{IPO underwritten by } B_2 \text{ if } V_i(1+\alpha_2)-\lambda_2-\mu_2 V_i \ge \max\left\{V_i(1+\alpha_1)-\lambda_1-\mu_1 V_i, V_i\right\},
\end{aligned}$$

and the resulting expected profits of each of the two banks, given by

$$\pi_j = \lambda_j N \sum_{i=1}^{1/G} (\mathbb{I}(i,j)G) + \mu_j N \sum_{i=1}^{1/G} (\mathbb{I}(i,j)iG) - \frac{c_j}{N_k}\left(N\sum_{i=1}^{1/G}(\mathbb{I}(i,j)G)\right)^2, \tag{47}$$

where $\mathbb{I}(i,j)=1$ if an IPO of firm with value $V_i = iG$ is underwritten by bank $j$ and $\mathbb{I}(i,j)=0$ otherwise.

For given $\lambda_1$ and $\mu_1$ we search for $B_2$'s best response (i.e. a combination of $\lambda_2$ and $\mu_2$ that results in the highest value of $\pi_2$ in (47), $\lambda_2'$ and $\mu_2'$). We then search for $\lambda_1'$ and $\mu_1'$, which are $B_1$'s best response to $\lambda_2'$ and $\mu_2'$, and we repeat this procedure until convergence. We use the resulting equilibrium $\lambda_1^*$, $\lambda_2^*$, $\mu_1^*$, and $\mu_2^*$ in the competitive and collusive scenarios to compute banks' equilibrium underwriting fee structures.

Figures 3–4 depict comparative statics of average proportional fees and average absolute fees of the two banks. The parameter values used in Figures 3 and 4 are: $\alpha_1 = 0.5$, $\alpha_2 = 0.3$, $c_1 = 0.1$, $c_2 = 0.1$, $k = 0.5$. Figure 3 presents the two banks' weighted average proportional fees in the competitive and collusive scenarios. The definition of the weighted average proportional fee in the case of variable underwriting fees has to be modified as follows:

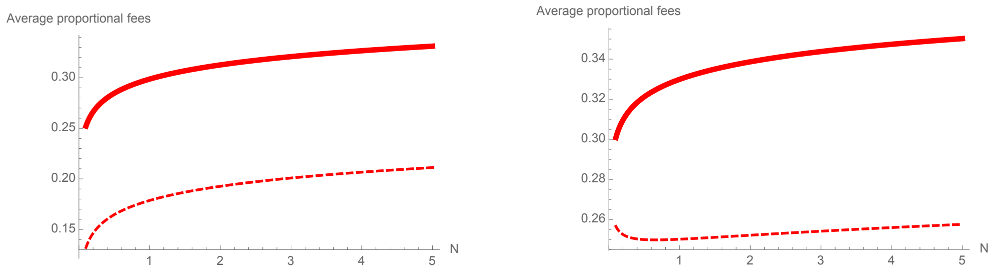
**Definition 2** *Bank j's weighted average proportional fee,* $\overline{RF_j}$, *equals* $\dfrac{\lambda_j\left(N\left(\overline{V_j}-\underline{V_j}\right)\right)+\mu_j N \int_{V=\underline{V_j}}^{\overline{V_j}} V dV}{N\int_{V=\underline{V_j}}^{\overline{V_j}} V dV}$.

Figure 3 shows that similar to the base-case model in Section 2, the two banks' average proportional fees are increasing in the demand for public incorporation in the competitive scenario. In the collusive scenario, on the other hand, the higher-quality bank's average absolute fee is increasing in $N$, whereas the lower-quality bank's average absolute fee exhibits a U-shaped relation with $N$.

Unlike in the base-case model in Section 2, in which the fees paid to a given underwriter are identical for all firms, underwriting fees are now increasing in IPO size. Thus, in order to relate the ratio of the two banks' fees to the demand for public incorporation, we first need to define an average absolute (dollar) fee charged by a bank:

**Figure 3: Average proportional fees: The case of optimal variable fees**

Figure 3A: Competitive case Figure 3B: Collusive case

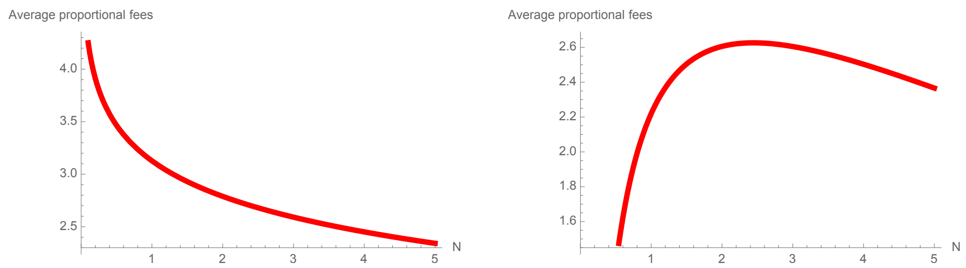



**Definition 3** *Bank j's average absolute fee, $\overline{F_j}$, equals* $\dfrac{\lambda_j N\left(\overline{V_j}-\underline{V_j}\right)+\mu_j N\int_{V=\underline{V_j}}^{\overline{V_j}} V\,dV}{N\left(\overline{V_j}-\underline{V_j}\right)}$.

Figure 4 depicts the relation between the ratio of the two banks' average absolute (dollar) fees and the demand for public incorporation. Similar to the base-case model in Section 2, the ratio of the two banks' average absolute fees is decreasing in the demand for public incorporation in the competitive scenario and it exhibits a hump-shaped relation with the demand for public incorporation in the collusive scenario. Overall, the results in this Appendix suggest that introducing variable underwriting fees does not affect the qualitative comparative statics derived in the baseline model.

**Figure 4: Ratio of absolute fees: The case of optimal variable fees**

Figure 4A: Competitive case Figure 4B: Collusive case




# D Perfect price discrimination

In this Appendix we solve the model of collusion that takes the form of perfect price discrimination and discuss its comparative statics and their relation to the empirical results in Section 3. The surplus from an IPO underwritten by the higher-quality bank, $V_i\alpha_1$, is higher than the surplus from an IPO underwritten by the lower-quality bank, $V_i\alpha_2$. Thus, the banks' joint profit is maximized when the most valuable IPOs are underwritten by $B_1$, until the point at which the marginal revenue of $B_1$ equals its marginal cost of underwriting. $B_2$ would underwrite IPOs with the highest value among those not underwritten by $B_1$ up to the point that its marginal revenue equals its marginal cost of underwriting.

It follows that the marginal revenue of $B_1$ from underwriting the $N_1$th IPO is

$$MR_1(N_1) = \alpha_1 \left(1 - \frac{N_1}{N}\right). \tag{48}$$

The marginal cost to $B_1$ of underwriting the $N_1$th IPOs is

$$MC_1(N_1) = 2\frac{c_1}{N^k}N_1. \tag{49}$$

Equating $MR_1(N_1)$ in (48) to $MC_1(N_1)$ in (49) and solving for $N_1$ results in the following equilibrium mass of IPOs underwritten by $B_1$:

$$N_1^* = \frac{N^{k+1}\alpha_1}{2Nc_1 + N^k\alpha_1} \tag{50}$$

The marginal revenue of $B_2$ from underwriting the $N_2$th IPO is

$$MR_2(N_1, N_2) = \alpha_2 \left(1 - \frac{N_1 + N_2}{N}\right). \tag{51}$$

The marginal cost to $B_2$ of underwriting the $N_2$th IPO is

$$MC_2(N_2) = 2\frac{c_2}{N^k}N_2. \tag{52}$$

Equating $MR_2(N_1, N_2)$ in (51) to $MC_2(N_2)$ in (52) and solving for $N_2$ results in the following equilibrium mass of IPOs underwritten by $B_2$:

$$N_2^* = \frac{2N^{k+2}c_1\alpha_2}{(2Nc_1 + N^k\alpha_1)(2Nc_2 + N^k\alpha_2)} \tag{53}$$

In the case of perfect price discrimination, the fee charged by bank $j$ for underwriting an IPO by a firm with value $V_i$ equals $F_{i,j} = V_i\alpha_j$ and the proportional underwriting fee equals $\alpha_j$. This immediately leads to the following result.

**Proposition 5** *Under collusion with perfect price discrimination, the average proportional underwriting fee of each bank is independent of the demand for public incorporation.*

The weighted average absolute fee is defined as follows:

**Definition 4** *Bank $j$'s weighted average absolute (dollar) fee, $\overline{F_j}$ equals $\frac{N \int_{V=\underline{V_j}}^{\overline{V_j}} \alpha_j V dV}{N\left(\overline{V_j} - \underline{V_j}\right)}$, where $\overline{V_1} = 1$, $\underline{V_1} = \overline{V_2} = 1 - \frac{N_1}{N}$, and $\underline{V_2} = 1 - \frac{N_1+N_2}{N}$.*

Computing the ratio of the average absolute fees of the two banks leads to the following proposition.

**Proposition 6** *Under collusion with perfect price discrimination, the ratio of the weighted average absolute (dollar) fee of the higher-quality bank ($B_1$), $\overline{F_1}^*$, to the weighted average absolute fee of the lower-quality bank ($B_2$), $\overline{F_2}^*$, is decreasing in $N$.*

**Proof.** Differentiating $\frac{\overline{F_1}^*}{\overline{F_2}^*}$ with respect to $N$ results in

$$\frac{\partial \frac{F_1^*}{F_2^*}}{\partial N} = -\frac{(1-k)\,\alpha_1^2\left(16N^3c_1c_2^2 + 8N^{2+k}c_2\left(c_2\alpha_1 + 2c_1\alpha_2\right) + N^{1+2k}\alpha_2\left(7c_2\alpha_1 + 2c_1\alpha_2\right) + N^{3k}\alpha_1\alpha_2^2\right)}{2N^{3-k}c_1^2\alpha_2\left(4Nc_2 + N^2\alpha_2\right)^2} < 0. \tag{54}$$

■

The intuition for the negative relation between the ratio of the average absolute fees on one hand and the demand for public incorporation on the other hand is as follows. In the case of perfect price discrimination, the average absolute fee of each bank equals the average value-added provided by that bank. The average value-added provided by bank $j$ depends on two factors: this bank's value-added parameter $\alpha_j$ and the average size of the IPOs underwritten by the bank. The ratio of $\alpha_1$ and $\alpha_2$ is constant. The ratio of the average IPO sizes is decreasing in $N$. The reason is that the range of IPOs underwritten by each bank narrows as $N$ increases. In the extreme, when $N$ is very large, both banks underwrite only the highest-valued IPOs, and the ratio of the two banks' fees approaches $\frac{\alpha_1}{\alpha_2}$. In the other extreme, when $N$ is very small, it is optimal for $B_1$ to underwrite almost all IPOs, and $B_2$ underwrites only the smallest IPOs. In this case, the ratio of the average IPO sizes of the two banks as well as the ratio of the two banks' average absolute fees approach infinity. As a result, the ratio of the average absolute fee of $B_1$ and that of $B_2$ is decreasing in $N$.

Propositions 5 and 6 are inconsistent with our empirical findings of a positive relation between higher-quality bank's proportional fee and the demand for public incorporation, a U-shaped relation between lower-quality bank's proportional fee and the demand for public incorporation, and a hump-shaped relation between the ratio of higher-quality bank's to lower-quality bank's absolute fees and the demand for public incorporation. This suggests that even if underwriters implicitly collude while deciding on IPO spreads and IPO pricing, it is unlikely that this implicit collusion takes the form of perfect price discrimination.

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## Table 1. Summary statistics

Panel A reports annual means of the number and value of IPOs and acquisitions of private firms by public ones. The sample consists of 6,917 IPOs by U.S. firms during 1975-2013 and 3,743 acquisitions during the period 1981-2013 in which a) the acquisition value equals or exceeds the lowest market value of equity among all firms going public in the year of the acquisition, and b) the target has hired a bank to provide merger advisory services. The source of data is Thomson Financial's Security Data Company and Jay Ritter. The sample of IPOs excludes non-firm-commitment offerings, unit offerings, offerings by banks, closed-end funds, REITs, and ADRs, reverse LBOs, IPOs with offer price lower than $5, and offerings that are part of a corporate spinoff. We also require IPOs to have information on underwriting spread and total proceeds. # IPOs is the number of IPOs in a given year. Value IPOs (in millions of dollars) is total annual IPO proceeds adjusted by the Consumer Price Index (CPI) to 2010 dollars. # Acquisitions is the number of acquisitions in which the targets satisfy the restrictions above in a given year. Value acquisitions (in millions of dollars) is total annual amount paid in acquisitions in which the targets satisfy the restrictions above adjusted by the Consumer Price Index (CPI) to 2010 dollars.

Panel B reports annual means of IPO and underwriter characteristics. Mean IPO spread refers to the value-weighted mean underwriter spread. Mean underpricing refers to value-weighted mean ratio of the share price at the end of the first trading day to the offer price, minus one. Mean underpricing ($> 0$) refers to value-weighted mean underpricing, where negative underpricing is replaced by 0. Prop. VC is the proportion of IPOs backed by venture capital funds. Prop hi-tech is the proportion of IPOs in hi-tech industries, where hi-tech is defined as in Loughran and Ritter (2004). Prop. sec. is the equally-weighted mean proportion of secondary shares in IPOs. Prop. synd. is the proportion of IPOs underwritten by multiple book runners. Prop. EW HQ (CM) (Prop. VW HQ (CM)) is the equally-weighted (value-weighted) proportion of IPOs underwritten by banks with Carter-Manaster score equal to or higher than 8. Prop. EW HQ (MS) (Prop. VW HQ (MS)) is the equally-weighted (value-weighted) proportion of IPOs underwritten by banks with top-15 time-weighed lagged market share.

Panel C presents summary statistics for the pooled sample. The variables are defined as in Panel B.

Panel D presents summary statistics of IPO underpricing for groups of underwriters classified by their reputation score (CM score), as in Carter and Manaster (1990) and Loughran and Ritter (2004). If an IPO has multiple book runners, we divide its proceeds evenly by the number of book runners and count this IPO multiple times. #underwriter-years refers to the sum over 39 years (1975–2013) of the annual number of underwriters belonging to a CM score group. #IPO refers to the number of IPOs underwritten by banks belonging to a given CM group. Value of IPOs refers to the sum of value of IPOs underwritten by banks belonging to a given CM group in 2010 dollars. % (# IPOs) is the percentage of IPOs underwritten by banks belonging to a given CM group. % (Value IPOs) is the percentage of the total value of IPOs underwritten by banks belonging to a given CM group. Mean value IPO refers to mean value of IPOs underwritten by banks belonging to a given CM group in 2010 dollars.

**Panel A. # IPOs and # acquisitions – by year**

| Year | # IPOs | Value IPOs | # Acq. | Value acq. | # IPOs + acq. | Value IPOs + acq. |
|---|---|---|---|---|---|---|
| 1975 | 12 | 1,105 | | | | |
| 1976 | 27 | 862 | | | | |
| 1977 | 19 | 501 | | | | |
| 1978 | 22 | 718 | | | | |
| 1979 | 45 | 1,042 | | | | |
| 1980 | 68 | 2,438 | | | | |
| 1981 | 177 | 5,097 | 39 | 9,797 | 216 | 14,893 |
| 1982 | 67 | 2,159 | 62 | 12,235 | 129 | 14,394 |
| 1983 | 453 | 16,839 | 63 | 14,374 | 516 | 31,213 |
| 1984 | 194 | 3,527 | 63 | 15,272 | 257 | 18,798 |
| 1985 | 187 | 6,042 | 36 | 8,586 | 223 | 14,628 |
| 1986 | 349 | 18,614 | 50 | 12,884 | 399 | 31,498 |
| 1987 | 254 | 15,759 | 41 | 11,118 | 295 | 26,877 |
| 1988 | 90 | 4,375 | 45 | 10,942 | 135 | 15,317 |
| 1989 | 100 | 4,764 | 33 | 5,423 | 133 | 10,187 |
| 1990 | 102 | 5,285 | 34 | 5,143 | 136 | 10,428 |
| 1991 | 256 | 17,967 | 27 | 2,895 | 283 | 20,862 |
| 1992 | 342 | 23,867 | 57 | 7,926 | 399 | 31,793 |
| 1993 | 402 | 22,954 | 95 | 7,910 | 497 | 30,864 |
| 1994 | 342 | 14,617 | 135 | 14,524 | 477 | 29,141 |
| 1995 | 412 | 25,860 | 175 | 24,814 | 587 | 50,674 |
| 1996 | 603 | 39,257 | 219 | 30,262 | 822 | 69,519 |
| 1997 | 402 | 28,455 | 256 | 50,133 | 658 | 78,588 |
| 1998 | 236 | 19,354 | 296 | 64,942 | 532 | 84,296 |
| 1999 | 397 | 57,267 | 266 | 76,461 | 663 | 133,728 |
| 2000 | 290 | 43,705 | 272 | 94,135 | 562 | 137,840 |
| 2001 | 60 | 17,782 | 131 | 36,229 | 191 | 54,012 |
| 2002 | 49 | 9,161 | 125 | 23,953 | 174 | 33,114 |
| 2003 | 52 | 9,238 | 117 | 23,444 | 169 | 32,682 |
| 2004 | 141 | 24,494 | 155 | 34,344 | 296 | 58,838 |
| 2005 | 127 | 25,847 | 161 | 48,481 | 288 | 74,328 |
| 2006 | 127 | 24,715 | 173 | 92,455 | 300 | 117,170 |
| 2007 | 125 | 28,561 | 154 | 44,251 | 279 | 72,812 |
| 2008 | 17 | 23,359 | 78 | 29,551 | 95 | 52,911 |
| 2009 | 35 | 12,425 | 39 | 12,146 | 74 | 24,571 |
| 2010 | 80 | 28,602 | 77 | 24,877 | 157 | 53,479 |
| 2011 | 70 | 23,634 | 82 | 34,827 | 152 | 58,461 |
| 2012 | 82 | 28,743 | 110 | 39,729 | 192 | 68,472 |
| 2013 | 121 | 26,251 | 77 | 24,331 | 198 | 50,582 |
| Mean | 178 | 17,057 | 113 | 28,739 | 318 | 48,696 |

### Panel B. IPO and underwriter characteristics – by year

| Year | Mean IPO spread | Mean u-pricing | Mean u-pricing (>0) | Prop. VC | Prop. Hi-tech | Prop. Sec. | Prop. Synd. | Prop. EW HQ (CM) | Prop. VW HQ (CM) | Prop. EW HQ (MS) | Prop. VW HQ (MS) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1975 | 7.15 | -0.21 | 2.30 | 0.000 | 0.000 | 0.529 | 0.000 | 0.750 | 0.948 | 1.000 | 1.000 |
| 1976 | 7.67 | 1.62 | 4.04 | 0.370 | 0.370 | 0.372 | 0.000 | 0.370 | 0.516 | 0.815 | 0.929 |
| 1977 | 8.34 | 7.99 | 8.89 | 0.211 | 0.316 | 0.268 | 0.000 | 0.316 | 0.575 | 0.842 | 0.984 |
| 1978 | 7.79 | 15.56 | 16.79 | 0.364 | 0.455 | 0.257 | 0.000 | 0.455 | 0.572 | 0.909 | 0.987 |
| 1979 | 8.16 | 14.93 | 16.34 | 0.311 | 0.489 | 0.290 | 0.000 | 0.333 | 0.466 | 0.533 | 0.732 |
| 1980 | 8.05 | 14.23 | 15.61 | 0.338 | 0.368 | 0.207 | 0.000 | 0.309 | 0.516 | 0.603 | 0.815 |
| 1981 | 7.95 | 6.35 | 7.20 | 0.305 | 0.418 | 0.208 | 0.000 | 0.181 | 0.302 | 0.384 | 0.616 |
| 1982 | 8.02 | 11.21 | 11.98 | 0.313 | 0.597 | 0.245 | 0.000 | 0.254 | 0.448 | 0.522 | 0.805 |
| 1983 | 8.02 | 12.20 | 13.42 | 0.245 | 0.450 | 0.184 | 0.000 | 0.265 | 0.493 | 0.377 | 0.667 |
| 1984 | 8.38 | 4.25 | 5.74 | 0.232 | 0.335 | 0.138 | 0.000 | 0.258 | 0.503 | 0.273 | 0.524 |
| 1985 | 8.09 | 7.99 | 8.67 | 0.198 | 0.251 | 0.188 | 0.000 | 0.401 | 0.667 | 0.348 | 0.570 |
| 1986 | 7.69 | 7.14 | 8.09 | 0.223 | 0.278 | 0.177 | 0.000 | 0.516 | 0.827 | 0.447 | 0.777 |
| 1987 | 7.70 | 6.60 | 7.31 | 0.256 | 0.287 | 0.136 | 0.000 | 0.520 | 0.862 | 0.453 | 0.819 |
| 1988 | 7.61 | 7.06 | 7.68 | 0.367 | 0.356 | 0.153 | 0.000 | 0.556 | 0.849 | 0.556 | 0.837 |
| 1989 | 7.52 | 9.34 | 9.63 | 0.390 | 0.370 | 0.197 | 0.000 | 0.610 | 0.837 | 0.560 | 0.775 |
| 1990 | 7.60 | 11.75 | 12.27 | 0.422 | 0.343 | 0.154 | 0.000 | 0.657 | 0.909 | 0.637 | 0.884 |
| 1991 | 7.27 | 12.91 | 13.28 | 0.445 | 0.391 | 0.144 | 0.000 | 0.680 | 0.865 | 0.641 | 0.852 |
| 1992 | 7.36 | 11.67 | 12.29 | 0.383 | 0.377 | 0.116 | 0.000 | 0.561 | 0.844 | 0.538 | 0.821 |
| 1993 | 7.39 | 14.45 | 14.92 | 0.403 | 0.333 | 0.115 | 0.002 | 0.529 | 0.769 | 0.464 | 0.702 |
| 1994 | 7.55 | 10.40 | 10.73 | 0.365 | 0.354 | 0.112 | 0.003 | 0.443 | 0.701 | 0.367 | 0.583 |
| 1995 | 7.38 | 22.78 | 23.13 | 0.444 | 0.515 | 0.138 | 0.000 | 0.578 | 0.807 | 0.556 | 0.787 |
| 1996 | 7.34 | 17.64 | 18.18 | 0.421 | 0.476 | 0.085 | 0.000 | 0.589 | 0.803 | 0.512 | 0.731 |
| 1997 | 7.30 | 14.46 | 14.82 | 0.328 | 0.403 | 0.090 | 0.002 | 0.563 | 0.791 | 0.501 | 0.748 |
| 1998 | 7.26 | 22.34 | 22.96 | 0.318 | 0.458 | 0.086 | 0.017 | 0.642 | 0.852 | 0.621 | 0.835 |
| 1999 | 7.02 | 72.18 | 73.20 | 0.645 | 0.806 | 0.039 | 0.025 | 0.818 | 0.938 | 0.794 | 0.923 |
| 2000 | 7.02 | 60.65 | 62.09 | 0.738 | 0.862 | 0.018 | 0.041 | 0.806 | 0.897 | 0.839 | 0.924 |
| 2001 | 6.87 | 15.91 | 16.85 | 0.450 | 0.400 | 0.058 | 0.167 | 0.814 | 0.963 | 0.886 | 0.983 |
| 2002 | 7.00 | 10.85 | 12.26 | 0.429 | 0.408 | 0.140 | 0.224 | 0.820 | 0.925 | 0.852 | 0.955 |
| 2003 | 7.04 | 12.43 | 13.66 | 0.404 | 0.404 | 0.155 | 0.308 | 0.725 | 0.836 | 0.855 | 0.921 |
| 2004 | 6.87 | 13.34 | 14.12 | 0.496 | 0.532 | 0.126 | 0.376 | 0.782 | 0.894 | 0.861 | 0.949 |
| 2005 | 6.80 | 10.70 | 11.81 | 0.299 | 0.394 | 0.157 | 0.512 | 0.768 | 0.889 | 0.815 | 0.912 |
| 2006 | 6.85 | 12.77 | 13.78 | 0.394 | 0.504 | 0.137 | 0.528 | 0.788 | 0.876 | 0.868 | 0.936 |
| 2007 | 6.85 | 14.34 | 15.90 | 0.488 | 0.656 | 0.140 | 0.584 | 0.793 | 0.909 | 0.847 | 0.950 |
| 2008 | 6.33 | 9.53 | 13.38 | 0.471 | 0.353 | 0.238 | 0.706 | 0.872 | 0.894 | 0.949 | 0.997 |
| 2009 | 6.42 | 11.56 | 12.60 | 0.343 | 0.400 | 0.343 | 0.886 | 0.887 | 0.953 | 0.990 | 0.997 |
| 2010 | 6.73 | 8.35 | 9.24 | 0.463 | 0.500 | 0.248 | 0.825 | 0.843 | 0.940 | 0.905 | 0.970 |
| 2011 | 6.51 | 14.33 | 16.45 | 0.600 | 0.586 | 0.221 | 0.857 | 0.878 | 0.934 | 0.918 | 0.963 |
| 2012 | 6.77 | 17.78 | 19.07 | 0.561 | 0.585 | 0.150 | 0.890 | 0.823 | 0.950 | 0.893 | 0.977 |
| 2013 | 6.71 | 24.29 | 26.04 | 0.587 | 0.612 | 0.054 | 0.909 | 0.798 | 0.898 | 0.838 | 0.916 |
| Mean | 7.34 | 14.71 | 15.81 | 0.385 | 0.436 | 0.175 | 0.202 | 0.604 | 0.780 | 0.681 | 0.848 |

**Panel C. Summary statistics – IPO characteristics**

| | Mean | St. Dev. | Min | Median | Max |
|---|---|---|---|---|---|
| Spread | 7.40% | 1.11% | 0.75% | 7.00% | 17.00% |
| Underpricing | 18.56% | 39.36% | -50.00% | 7.14% | 697.50% |
| Underpricing (> 0) | 19.36% | 38.86% | 0.00% | 7.14% | 697.50% |
| Prop. VC | 0.395 | 0.489 | 0.000 | 0.000 | 1.000 |
| Prop. hi-tech | 0.456 | 0.498 | 0.000 | 0.000 | 1.000 |
| Prop. secondary | 0.131 | 0.207 | 0.000 | 0.000 | 1.000 |
| Prop. mult. bookrunners | 0.098 | 0.297 | 0.000 | 0.000 | 1.000 |

**Panel D. Summary statistics – Book runners by reputation score**

| CM score | #underwriter-years | # IPOs | Value IPOs | % (# IPOs) | % (Value IPOs) | Mean value IPO |
|---|---|---|---|---|---|---|
| [8, 9] | 590 | 3919 | 562,298 | 56.56% | 85.36% | 114.47 |
| [7, 8) | 308 | 809 | 44,818 | 11.67% | 6.80% | 50.24 |
| [6, 7) | 208 | 437 | 18,452 | 6.30% | 2.80% | 39.01 |
| [5, 6) | 331 | 562 | 16,688 | 8.11% | 2.53% | 28.97 |
| [4, 5) | 169 | 278 | 4,114 | 4.01% | 0.62% | 14.64 |
| [3, 4) | 257 | 382 | 5,673 | 5.51% | 0.86% | 14.81 |
| [2, 3) | 251 | 375 | 4,111 | 5.41% | 0.62% | 10.88 |
| [0, 2) | 112 | 168 | 2,510 | 2.45% | 0.40% | 11.81 |

**Table 2. Proportional underwriter compensation, underwriter quality, and the demand for public incorporation**

This table presents estimates of regressions in (23), in which the dependent variable is weighted average annual proportional underwriter compensation. We compute proportional underwriter compensation in a given IPO as a combination of direct compensation (underwriting spread) and indirect compensation (ranging between 0% and 65% of positive underpricing). Weighted average proportional compensation is the ratio of the sum of compensations received by a given bank for all IPOs it underwrote in a given year to the sum of proceeds of all IPOs it underwrote in that year. The main independent variables are the demand for public incorporation interacted with high quality and low quality underwriter indicators (HQ and LQ respectively), and the demand for public incorporation squared interacted with HQ and LQ. In Panel A, the demand for public incorporation is proxied by the annual number of IPOs multiplied by 0.01, $(\#IPOs*0.01)$. In Panel B, the demand for public incorporation is proxied by the sum of the annual number of IPOs and the annual number of acquisitions of private firms by public ones in which a) the acquisition value equals or exceeds the lowest market value of equity among all firms going public in the year of the acquisition, and b) the target has hired a bank to provide merger advisory services, $((\#IPOs + \#Acq.) * 0.01)$. HQ (high quality) dummy is an indicator variable equalling one if an underwriter belongs to the group of top underwriters. This group contains underwriters with Carter-Manaster score equalling or exceeding 9 (in columns 1-5), and those with the highest 15 lagged market shares of IPO underwriting, based on weighed \$ amount of IPOs underwritten in the last 5 years (in columns 6-10). The other independent variables are underwriter-year means of the following IPO-level variables: IPO size, which is the natural logarithm of IPO proceeds net of underwriting spread, and including of over allotment option if exercised; Secondary, which is the proportion of secondary shares sold by existing shareholders in an IPO; Hi-tech, which is an indicator variable equalling one for hi-tech issuers; VC, which is an indicator variable equalling one for VC-backed IPOs; and Syndicate, which is an indicator equalling one for IPOs with joint book runners. The regressions are performed at the underwriter-year level. Standard errors are clustered by underwriter. t-statistics are reported in parentheses. Inflection point (HQ) is computed when the coefficients on $(\#IPOs * 0.01)$ * HQ and $(\#IPOs * 0.01)^2$ * HQ (in Panel A) and $((\#IPOs + \#Acq.) * 0.01)$ * HQ and $((\#IPOs + \#Acq.) * 0.01)^2$ * HQ (in Panel B) have different signs. Inflection point equals minus one half times the ratio of the coefficient on $(\#IPOs * 0.01)$ *HQ to the coefficient on $(\#IPOs * 0.01)^2$ * HQ (in Panel A) and minus one half times the ratio of the coefficient on $((\#IPOs + \#Acq.) * 0.01)$ *HQ to the coefficient on $((\#IPOs + \#Acq.) * 0.01)^2$ * HQ (in Panel B). Inflection point (LQ) is computed similarly.

**Panel A. Demand for public incorporation proxied by #IPOs**

| Measure of high quality | Carter-Manaster score $\geq 8$ | | | | | Rank(past market share) $\leq 15$ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Measure of compensation | Direct +0% | Direct +10% | Direct +20% | Direct +30% | Direct +65% | Direct +0% | Direct +10% | Direct +20% | Direct +30% | Direct +65% |
| $(\#IPO * 0.01)$ * HQ | 0.044 | 0.082 | 0.120 | 0.158 | 0.292 | 0.143 | 0.260 | 0.376 | 0.493 | 0.900 |
| | (0.52) | (0.38) | (0.31) | (0.28) | (0.25) | (1.63) | (1.14) | (0.91) | (0.82) | (0.71) |
| $(\#IPO * 0.01)^2$ * HQ | -0.013 | 0.009 | 0.032 | 0.055 | 0.135 | -0.032 | -0.011 | 0.011 | 0.032 | 0.107 |
| | (-0.80) | (0.21) | (0.41) | (0.48) | (0.56) | (-1.87) | (-0.23) | (0.13) | (0.27) | (0.42) |
| $(\#IPO * 0.01)$ * LQ | -0.177 | -0.548 | -0.918 | -1.289 | -2.586 | -0.166 | -0.517 | -0.867 | -1.217 | -2.442 |
| | (-2.24) | (-2.97) | (-2.75) | (-2.64) | (-2.49) | (-2.16) | (-2.84) | (-2.64) | (-2.53) | (-2.39) |
| $(\#IPO * 0.01)^2$ * LQ | 0.035 | 0.155 | 0.276 | 0.396 | 0.818 | 0.034 | 0.149 | 0.265 | 0.380 | 0.784 |
| | (2.49) | (4.17) | (4.02) | (3.94) | (3.82) | (2.49) | (4.08) | (3.92) | (3.84) | (3.72) |
| IPO size | -0.997 | -0.949 | -0.900 | -0.851 | -0.680 | -1.009 | -0.992 | -0.974 | -0.957 | -0.896 |
| | (-28.92) | (-11.04) | (-5.92) | (-3.87) | (-1.48) | (-32.17) | (-11.95) | (-6.54) | (-4.42) | (-1.97) |
| Secondary | -0.937 | -2.366 | -3.795 | -5.224 | -10.225 | -0.964 | -2.432 | -3.899 | -5.366 | -10.501 |
| | (-8.03) | (-8.68) | (-7.78) | (-7.35) | (-6.82) | (-8.40) | (-9.01) | (-8.02) | (-7.56) | (-6.99) |
| Hi-tech | 0.090 | 0.721 | 1.353 | 1.984 | 4.194 | 0.087 | 0.713 | 1.338 | 1.964 | 4.155 |
| | (1.67) | (4.76) | (4.82) | (4.81) | (4.77) | (1.62) | (4.73) | (4.79) | (4.78) | (4.74) |
| VC | -0.429 | -0.506 | -0.582 | -0.658 | -0.924 | -0.438 | -0.536 | -0.634 | -0.732 | -1.075 |
| | (-7.12) | (-3.32) | (-2.09) | (-1.62) | (-1.07) | (-7.29) | (-3.51) | (-2.28) | (-1.79) | (-1.24) |
| Syndicate | 0.436 | 0.652 | 0.867 | 1.082 | 1.835 | 0.446 | 0.714 | 0.983 | 1.251 | 2.191 |
| | (5.28) | (3.33) | (2.53) | (2.19) | (1.78) | (5.78) | (3.78) | (2.94) | (2.58) | (2.16) |
| Intercept | 11.443 | 12.474 | 13.504 | 14.535 | 18.142 | 11.454 | 12.555 | 13.657 | 14.758 | 18.613 |
| | (71.24) | (31.45) | (19.06) | (14.11) | (8.37) | (75.10) | (32.67) | (19.77) | (14.67) | (8.77) |
| Inflection point (HQ) | 1.64 | | | | | 2.23 | 12.23 | | | |
| Inflection point (LQ) | 2.54 | 1.76 | 1.67 | 1.63 | 1.58 | 2.46 | 1.73 | 1.64 | 1.60 | 1.56 |
| R squared | 0.693 | 0.241 | 0.124 | 0.093 | 0.071 | 0.695 | 0.244 | 0.127 | 0.096 | 0.074 |
| # Obs. | 2,203 | 2,203 | 2,203 | 2,203 | 2,203 | 2,203 | 2,203 | 2,203 | 2,203 | 2,203 |

**Panel B. Demand for public incorporation proxied by #IPOs+#Acquisitions**

| Measure of high quality | Carter-Manaster score $\geq 8$ | | | | | Rank(past market share) $\leq 15$ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Measure of compensation | Direct +0% | Direct +10% | Direct +20% | Direct +30% | Direct +65% | Direct +0% | Direct +10% | Direct +20% | Direct +30% | Direct +65% |
| $((\#IPO + \#Acq.) * 0.01)$ * HQ | 0.036 | 0.020 | 0.004 | -0.012 | -0.069 | 0.084 | 0.100 | 0.117 | 0.134 | 0.192 |
| | (0.83) | (0.19) | (0.02) | (-0.05) | (-0.12) | (1.80) | (0.91) | (0.59) | (0.46) | (0.31) |
| $(\#IPO + \#Acq.) * 0.01)^2$ * HQ | -0.004 | 0.026 | 0.056 | 0.086 | 0.191 | -0.008 | 0.025 | 0.058 | 0.092 | 0.208 |
| | (-0.75) | (2.09) | (2.49) | (2.61) | (2.73) | (-1.49) | (1.81) | (2.30) | (2.47) | (2.64) |
| $((\#IPO + \#Acq.) * 0.01)$ * LQ | -0.075 | -0.162 | -0.249 | -0.335 | -0.639 | -0.072 | -0.165 | -0.259 | -0.352 | -0.679 |
| | (-3.04) | (-2.23) | (-2.62) | (-2.48) | (-2.24) | (-2.99) | (-2.47) | (-2.22) | (-2.04) | (-1.89) |
| $(\#IPO + \#Acq.) * 0.01)^2$ * LQ | 0.008 | 0.038 | 0.068 | 0.098 | 0.202 | 0.008 | 0.039 | 0.069 | 0.100 | 0.206 |
| | (1.87) | (2.85) | (2.74) | (2.69) | (2.61) | (1.93) | (3.05) | (2.94) | (2.88) | (2.81) |
| IPO size | -1.007 | -1.025 | -1.043 | -1.060 | -1.123 | -1.021 | -1.073 | -1.125 | -1.177 | -1.358 |
| | (-29.44) | (-11.82) | (-6.77) | (-4.75) | (-2.40) | (-32.90) | (-12.76) | (-7.42) | (-5.33) | (-2.92) |
| Secondary | -0.927 | -2.027 | -3.127 | -4.227 | -8.078 | -0.941 | -2.049 | -3.158 | -4.267 | -8.147 |
| | (-7.77) | (-7.75) | (-6.73) | (-6.25) | (-5.66) | (-7.87) | (-7.85) | (-6.80) | (-6.32) | (-5.71) |
| Hi-tech | 0.093 | 0.680 | 1.268 | 1.855 | 3.911 | 0.089 | 0.665 | 1.242 | 1.819 | 3.838 |
| | (1.72) | (4.55) | (4.60) | (4.58) | (4.55) | (1.65) | (4.49) | (4.54) | (4.53) | (4.49) |
| VC | -0.436 | -0.510 | -0.584 | -0.658 | -0.917 | -0.443 | -0.533 | -0.622 | -0.711 | -1.023 |
| | (-7.25) | (-3.34) | (-2.09) | (-1.61) | (-1.06) | (-7.39) | (-3.49) | (-2.23) | (-1.74) | (-1.18) |
| Syndicate | 0.465 | 0.832 | 1.200 | 1.567 | 2.852 | 0.465 | 0.868 | 1.271 | 1.673 | 3.083 |
| | (5.56) | (4.24) | (3.53) | (3.21) | (2.82) | (6.13) | (4.64) | (3.88) | (3.55) | (3.14) |
| Intercept | 11.439 | 12.507 | 13.576 | 14.645 | 18.385 | 11.467 | 12.638 | 13.809 | 14.981 | 19.081 |
| | (76.42) | (33.93) | (20.73) | (15.42) | (9.23) | (80.26) | (35.14) | (21.46) | (16.02) | (9.70) |
| Inflection Point (HQ) | 4.70 | | | 0.07 | 0.18 | 5.09 | | | | |
| Inflection Point (LQ) | 4.59 | 2.13 | 1.83 | 1.72 | 1.58 | 4.42 | 2.14 | 1.87 | 1.77 | 1.65 |
| R squared | 0.694 | 0.244 | 0.129 | 0.099 | 0.078 | 0.696 | 0.250 | 0.135 | 0.105 | 0.083 |
| # Obs. | 2,068 | 2,068 | 2,068 | 2,068 | 2,068 | 2,068 | 2,068 | 2,068 | 2,068 | 2,068 |

## Table 3. Ratio of high-quality to low-quality underwriter absolute compensation and the demand for public incorporation

This table presents the estimates of regressions in (24), in which the dependent variable is the natural logarithm of the ratio of annual mean absolute (dollar) compensation of an underwriter that belongs to the high quality (HQ) group to annual mean absolute (dollar) compensation of an underwriter that belongs to the LQ group. Mean absolute (dollar) underwriter compensation equals the ratio of the sum of compensation received by the underwriter in a given year to the number of IPO underwritten by that underwriter in that year. We compute absolute (dollar) underwriter compensation as a combination of direct proportional compensation (underwriting spread) and indirect compensation (positive underpricing multiplied by a coefficient ranging between 0% and 65%), multiplied by IPO proceeds. The main independent variables are the demand for public incorporation and the demand for public incorporation squared. In Panel A, the demand for public incorporation is proxied by the annual number of IPOs multiplied by 0.01, ($\#IPOs * 0.01$). In Panel B, the demand for public incorporation is proxied by the sum of the annual number of IPOs and the annual number of acquisitions in which a) the acquisition value equals or exceeds the lowest market value of equity among all firms going public in the year of the acquisition, and b) the target has hired a bank to provide merger advisory services, ($(\#IPOs + \#Acq.) * 0.01$). The group of high quality underwriters contains underwriters with Carter-Manaster score equalling or exceeding 8 (in columns 1-5), and those with the highest 15 lagged market shares of IPO underwriting, based on weighed \$ amount of IPOs underwritten in the last 5 years (in columns 6-10). Other independent variables refer to the difference between annual mean of a variable for a HQ underwriter and annual mean value of the variable for a LQ underwriter. IPO size is the natural logarithm of IPO proceeds net of underwriting spread. Secondary is the proportion of secondary shares in an IPO. Hi-tech is an indicator variable equalling one for hi-tech issuers. VC is an indicator variable equalling one for VC-backed IPOs. Syndicate is an indicator equalling one for IPOs with joint book runners. The regressions are performed at the underwriter-pair level. Standard errors are clustered by underwriter. t-statistics are reported in parentheses. Inflection point (HQ) is computed when the coefficients on $\#IPOs * 0.01$ and $(\#IPOs * 0.01)^2$ (in Panel A) and $(\#IPOs + \#Acq.) * 0.01$ and $((\#IPOs + \#Acq.) * 0.01)^2$ (in Panel B) have different signs. Inflection point equals minus one half times the ratio of the coefficient on $\#IPOs * 0.01$ to the coefficient on $(\#IPOs * 0.01)^2$ (in Panel A) and minus one half times the ratio of the coefficient on $((\#IPOs + \#Acq.) * 0.01)$ to the coefficient on $((\#IPOs + \#Acq.) * 0.01)^2$ (in Panel B).

**Panel A. Demand for public incorporation proxied by #IPOs**

| Measure of high quality | Carter-Manaster score $\geq 8$ | | | | | Rank(past market share) $\leq 15$ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Measure of compensation | Direct +0% | Direct +10% | Direct +20% | Direct +30% | Direct +65% | Direct +0% | Direct +10% | Direct +20% | Direct +30% | Direct +65% |
| $(\#IPO * 0.01)$ | 0.066 | 0.085 | 0.091 | 0.094 | 0.096 | 0.067 | 0.079 | 0.081 | 0.081 | 0.077 |
| | (4.98) | (5.27) | (4.37) | (3.73) | (2.65) | (4.40) | (4.38) | (3.58) | (3.00) | (2.00) |
| $(\#IPO * 0.01)^2$ | -0.008 | -0.011 | -0.012 | -0.012 | -0.012 | -0.008 | -0.010 | -0.010 | -0.010 | -0.008 |
| | (-3.70) | (-4.56) | (-3.77) | (-3.18) | (-2.15) | (-3.61) | (-3.44) | (-2.65) | (-2.13) | (-1.28) |
| IPO size | 0.943 | 0.945 | 0.948 | 0.952 | 0.964 | 0.936 | 0.932 | 0.931 | 0.932 | 0.936 |
| | (102.00) | (82.57) | (67.62) | (58.07) | (42.12) | (95.85) | (80.60) | (67.35) | (58.24) | (41.95) |
| Secondary | -0.104 | -0.147 | -0.160 | -0.163 | -0.153 | -0.141 | -0.200 | -0.226 | -0.239 | -0.253 |
| | (-3.30) | (-3.45) | (-3.02) | (-2.63) | (-1.76) | (-4.62) | (-5.24) | (-4.64) | (-4.11) | (-3.02) |
| Hi-tech | 0.022 | 0.069 | 0.100 | 0.123 | 0.178 | 0.023 | 0.069 | 0.100 | 0.123 | 0.179 |
| | (2.37) | (5.43) | (5.96) | (6.10) | (6.14) | (2.23) | (5.75) | (6.54) | (6.78) | (6.92) |
| VC | -0.038 | -0.023 | -0.017 | -0.013 | -0.011 | -0.045 | -0.017 | -0.003 | 0.006 | 0.022 |
| | (-4.98) | (-1.59) | (-0.81) | (-0.53) | (-0.30) | (-4.03) | (-1.23) | (-0.18) | (0.27) | (0.71) |
| Syndicate | -0.738 | -0.623 | -0.546 | -0.489 | -0.356 | -0.776 | -0.669 | -0.595 | -0.537 | -0.400 |
| | (-31.17) | (-13.97) | (-8.68) | (-6.35) | (-3.28) | (-31.32) | (-19.00) | (-12.60) | (-9.39) | (-4.91) |
| Intercept | -0.087 | -0.086 | -0.080 | -0.075 | -0.057 | -0.034 | -0.005 | 0.022 | 0.044 | 0.105 |
| | (-4.56) | (-3.86) | (-2.88) | (-2.23) | (-1.16) | (-1.62) | (-0.19) | (0.71) | (1.21) | (1.97) |
| Inflection point | 4.31 | 3.80 | 3.75 | 3.78 | 3.96 | 4.04 | 3.92 | 4.03 | 4.17 | 4.66 |
| R squared | 0.936 | 0.872 | 0.795 | 0.730 | 0.583 | 0.929 | 0.869 | 0.794 | 0.730 | 0.583 |
| # Obs. | 29,017 | 29,017 | 29,017 | 29,017 | 29,017 | 24,369 | 24,369 | 24,369 | 24,369 | 24,369 |

**Panel B. Demand for public incorporation proxied by #IPOs+#Acquisitions**

| Measure of high quality | Carter-Manaster score $\geq 8$ | | | | | Rank(past market share) $\leq 15$ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Measure of compensation | Direct +0% | Direct +10% | Direct +20% | Direct +30% | Direct +65% | Direct +0% | Direct +10% | Direct +20% | Direct +30% | Direct +65% |
| $((\#IPO + \#Acq.) * 0.01)$ | 0.071 | 0.093 | 0.104 | 0.111 | 0.123 | 0.064 | 0.090 | 0.105 | 0.117 | 0.142 |
| | (5.30) | (7.15) | (6.30) | (5.51) | (4.12) | (4.96) | (6.19) | (5.73) | (5.30) | (4.54) |
| $((\#IPO + \#Acq.) * 0.01)^2$ | -0.006 | -0.007 | -0.008 | -0.008 | -0.008 | -0.005 | -0.007 | -0.007 | -0.008 | -0.009 |
| | (-4.15) | (-5.39) | (-4.50) | (-3.76) | (-2.48) | (-4.05) | (-4.38) | (-3.58) | (-3.10) | (-2.43) |
| IPO size | 0.945 | 0.944 | 0.946 | 0.949 | 0.959 | 0.937 | 0.930 | 0.928 | 0.928 | 0.931 |
| | (97.29) | (80.84) | (67.30) | (58.31) | (42.72) | (91.58) | (79.67) | (68.21) | (59.81) | (43.75) |
| Secondary | -0.102 | -0.120 | -0.114 | -0.103 | -0.055 | -0.135 | -0.165 | -0.168 | -0.164 | -0.136 |
| | (-2.99) | (-2.65) | (-2.06) | (-1.60) | (-0.62) | (-4.04) | (-3.91) | (-3.11) | (-2.52) | (-1.42) |
| Hi-tech | 0.021 | 0.069 | 0.100 | 0.124 | 0.179 | 0.019 | 0.065 | 0.095 | 0.119 | 0.175 |
| | (2.19) | (5.35) | (5.97) | (6.16) | (6.28) | (1.72) | (5.35) | (6.39) | (6.77) | (7.14) |
| VC | -0.036 | -0.025 | -0.023 | -0.022 | -0.027 | -0.038 | -0.013 | -0.001 | 0.006 | 0.016 |
| | (-4.47) | (-1.69) | (-1.07) | (-0.86) | (-0.72) | (-3.17) | (-0.91) | (-0.08) | (0.26) | (0.54) |
| Syndicate | -0.760 | -0.628 | -0.541 | -0.476 | -0.326 | -0.793 | -0.667 | -0.581 | -0.515 | -0.358 |
| | (-30.50) | (-14.66) | (-9.15) | (-6.64) | (-3.25) | (-30.10) | (-19.75) | (-13.31) | (-9.84) | (-4.83) |
| Intercept | -0.146 | -0.192 | -0.217 | -0.235 | -0.266 | -0.082 | -0.117 | -0.137 | -0.149 | -0.171 |
| | (-5.19) | (-7.50) | (-7.05) | (-6.23) | (-4.52) | (-3.07) | (-3.94) | (-3.74) | (-3.45) | (-2.75) |
| Inflection point | 5.89 | 6.28 | 6.68 | 7.04 | 8.05 | 5.95 | 6.62 | 7.06 | 7.36 | 7.88 |
| R squared | 0.936 | 0.873 | 0.797 | 0.733 | 0.589 | 0.931 | 0.873 | 0.802 | 0.740 | 0.599 |
| # Obs. | 28,285 | 28,285 | 28,285 | 28,285 | 28,285 | 23,595 | 23,595 | 23,595 | 23,595 | 23,595 |